

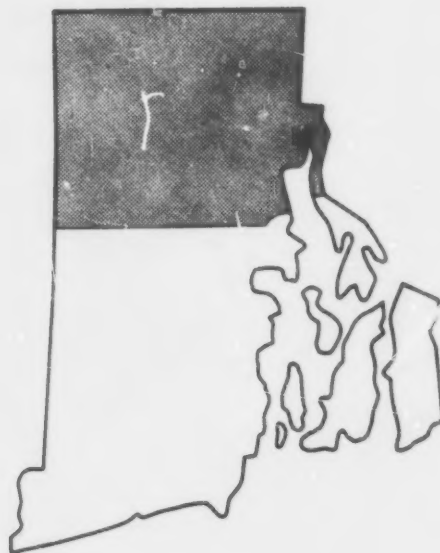
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FLOOD INSURANCE STUDY



COMPLETED

CITY OF
PROVIDENCE,
RHODE ISLAND
PROVIDENCE COUNTY



APRIL 15, 1986



Federal Emergency Management Agency

COMMUNITY NUMBER - 445406

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Flood Insurance Rate Map

FLOOD INSURANCE STUDY
CITY OF PROVIDENCE, RHODE ISLAND

1.0 INTRODUCTION

1.1 Purpose of Study

This Flood Insurance Study investigates the existence and severity of flood hazards in the City of Providence, Providence County, Rhode Island, and aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This study has developed flood risk data for various areas of the community that will be used to establish actuarial flood insurance rates and assist the community in their efforts to promote sound flood plain management. Minimum flood plain management requirements for participation in the National Flood Insurance Program are set forth in the Code of Federal Regulations at 44 CFR, 60.3.

In some states or communities, flood plain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum Federal requirements. In such cases, the more restrictive criteria take precedence and the state (or other jurisdictional agency) will be able to explain them.

1.2 Authority and Acknowledgments

The sources of authority for this Flood Insurance Study are the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

The hydrologic and hydraulic analyses in this study represent a revision of the original analyses performed by the New England Division of the U. S. Army Corps of Engineers. The updated version was prepared by PRC Engineering for the Federal Emergency Management Agency (FEMA), under Contract No. H-4776. The riverine analysis was completed in August 1980; the wave height analysis was completed in January 1984.

1.3 Coordination

In April 1978, community base map selection and the identification of streams requiring detailed study were performed at an initial Consultation and Coordination Officer's (CCO) meeting attended by representatives of FEMA, the City of Providence, and PRC Engineering (the study contractor).

An intermediate CCO meeting was held in November 1980 to discuss flood profiles, flood boundaries, and floodway delineations. An additional meeting was held in April 1983 to discuss the city's redevelopment project in the capital area. As a result of this meeting, it was decided to include the effects of a proposed conduit for diversion of flood flows away from the redevelopment area. This meeting was attended by consultants to the city for the redevelopment, including DeLeuw Cather/Parsons, Lee Pare Assoc., C. E. Maguire Inc., and Urban Consultants, as well as representatives of the city, the Rhode Island Departments of Building and Transportation, Amtrak, the Metropolitan District Commission (MDC), FEMA, and the study contractor.

A second intermediate CCO meeting was held on March 2, 1984, to discuss the preliminary results of the study and the wave height analysis. Representatives of the study contractor and the city attended this meeting.

During the course of the study, the New England Division of the U. S. Army Corps of Engineers (COE) furnished tide gage records at Providence and Newport, historic flood elevations throughout the Narragansett Bay area, and elevation-frequency relationships at Providence and Fall River. DeLeuw Cather/Parsons, and Lee Pare Assoc. furnished design plans and computations for the proposed flood diversion conduit.

On May 28, 1985, the results of the study were reviewed at a final CCO meeting held with representatives of FEMA, the city, and the study contractor.

2.0 AREA STUDIED

2.1 Scope of Study

This Flood Insurance Study covers the incorporated area of the City of Providence, Providence County, Rhode Island. The area of study is shown on the Vicinity Map (Figure 1).

Riverine flooding on the following streams was studied by detailed methods: the Providence River from the Fox Point Hurricane Barrier to the confluence of the Woonasquatucket and Moshassuck Rivers; the Woonasquatucket River from the confluence of the Moshassuck River to the upstream corporate limits; the Moshassuck River from its confluence with the Woonasquatucket River to the upstream corporate limits; the West River from its confluence with the Moshassuck River to the upstream corporate limits; Upper Canada Pond Brook from its confluence with the West River to the upstream corporate limits; and the entire length of the Pocasset River within the corporate limits. An area of shallow flooding

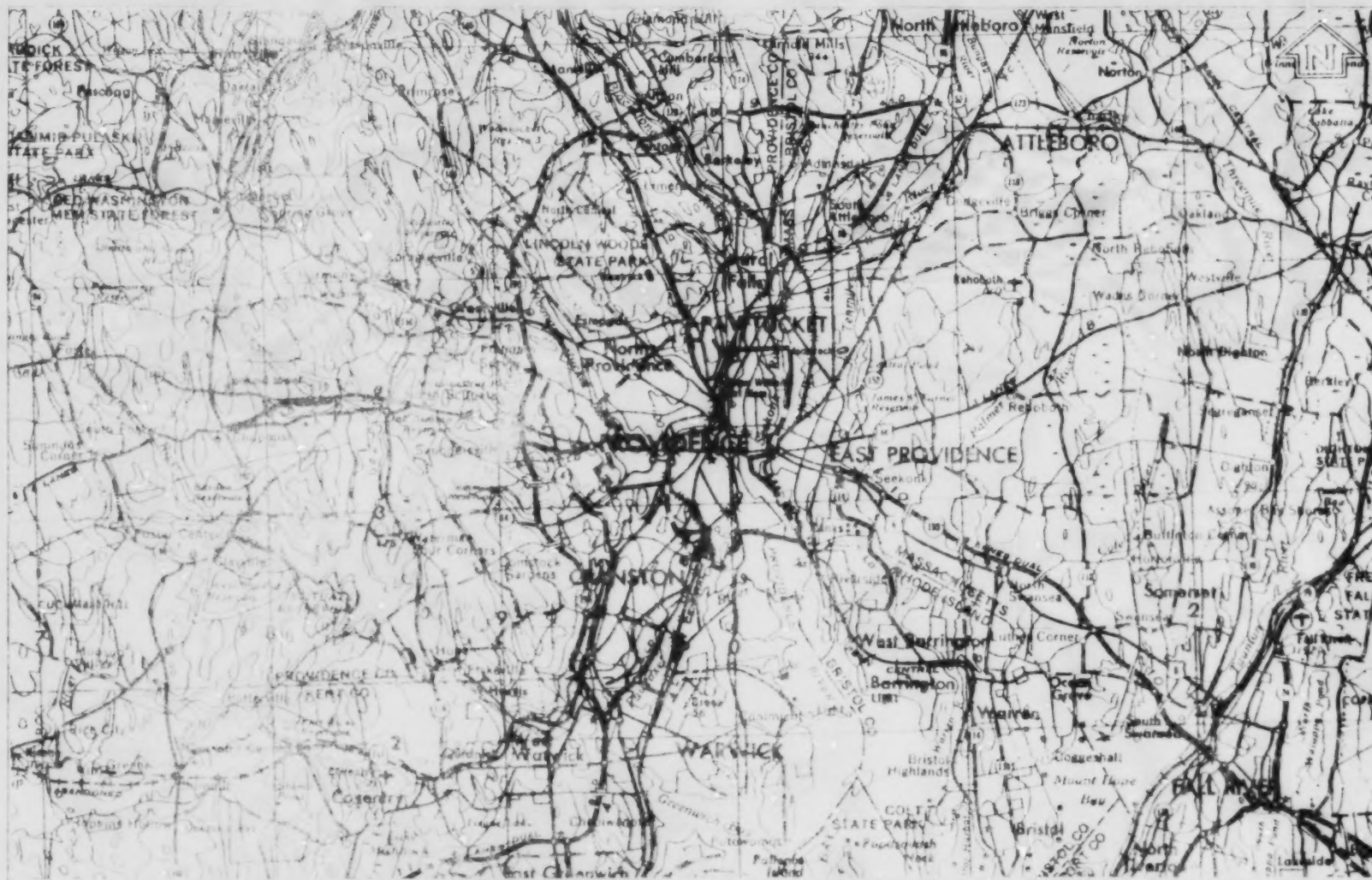


FIGURE 1

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVIDENCE, RI
(PROVIDENCE CO.)

APPROXIMATE SCALE



VICINITY MAP

along Amtrak from 900 feet north of Charles Street to 50 feet south of Smith Street and a ponding area south of the intersection of Charles Street and Admiral Street were included in the detailed study. Tidal flooding including its wave action from the Providence River and the Seekonk River was also studied by detailed methods. The areas studied by detailed methods were selected with priority given to all known flood hazard areas and areas of projected development and proposed construction through January 1989.

Elm Lake, Deep Spring Lake, Cunliff Lake, Edgewood Lake, Pleasure Lake, Roosevelt Lake, Polo Lake, Mashapaug Pond, and several small depression areas were studied by approximate methods. Approximate analyses were used to study those areas having a low development potential or minimal flood hazards. The scope and methods of study were proposed to, and agreed upon by, FEMA and the City of Providence.

2.2 Community Description

The City of Providence, which is the state capital, is located in the eastern portion of Providence County in eastern Rhode Island. It is bordered by the City of Pawtucket and the Town of North Providence to the north, the Town of Johnston to the west, the City of Cranston to the south, and the City of East Providence to the east. The Providence and Seekonk Rivers flow along the eastern border between Providence and East Providence.

Providence ranked first in population among cities and towns in Rhode Island in 1970, with a population of 179,116. The city has a total land area of 20 square miles, which yielded a 1970 population density of 9,900 persons per square mile. The economy of the city is dominated by manufacturing industries, including jewelry and silver, fabricated metals, printing, and electrical machinery.

The climate of Providence is typical of the North Temperate Zone, with a mean annual temperature of approximately 50 degrees Fahrenheit. The mean annual precipitation is 39.4 inches, including an average snowfall approximating 40 inches, though snowfall can occur in appreciably larger amounts (Reference 1).

The topography is variable, consisting of hills, lowlands, and swamps. Relief ranges from a high of 250 feet at Newtaconkanut Hill Park along the western corporate limits to a low of sea level at the eastern corporate limits.

Industrial and residential flood plain development has occurred extensively throughout Providence. South of Glenbridge Avenue to the Providence River, the Woonasquatucket River flood plain is heavily

developed with a mixture of industrial and residential development. North of Glenbridge Avenue, development on the Woonasquatucket River is generally confined to residential housing. The Moshassuck River flood plain is heavily developed with industries and residential land from below the North Burial Ground to the confluence with the Woonasquatucket River. The West River flood plain is heavily developed throughout the river's course in Providence, while the flood plain of Upper Canada Pond Brook contains residential development. The portion of the flood plain in Providence affected by the Pocasset River consists generally of industrial development. The coastline along the Providence River is heavily developed with industrial facilities, as is the lower portion of the Seekonk River.

The Woonasquatucket River rises in North Smithfield and enters Providence from the west through the Town of Johnston. Along its course, it passes through many reservoirs and old mill ponds.

The Moshassuck River rises in Lincoln and continues south into Providence where it joins with the Woonasquatucket River to form the Providence River. Adjacent to the North Burial Ground and Interstate 95, the Moshassuck River enters a 0.5-mile long culvert which terminates just north of the confluence of the West River. The West River enters the city from the northwest and is also characterized by several old mill ponds with heavy industrial development. Upper Canada Pond Brook enters Providence in the north from its headwaters in North Providence. The portion of this stream within Providence is dominated by Upper Canada Pond. The Pocasset River flows from Johnston through the southwestern corner of Providence at the Johnston-Cranston corporate limits.

Providence Harbor and the Providence River form the northern end of Narragansett Bay, ending at the Fox Point Hurricane Barrier. The Seekonk River branches from the Providence River and is tidally affected throughout its length in Providence.

2.3 Principal Flood Problems

The City of Providence has a history of severe flooding dating back to the 1600s. The most devastating floods of this century were the result of hurricane tidal surges and accompanying rainfall. On September 21, 1938, a hurricane struck the Connecticut-Rhode Island coastline just hours before the expected high tide in Providence. Peak winds of over 120 miles an hour blowing up Narragansett Bay created a tidal surge that inundated the downtown commercial area of Providence with over 10 feet of water. In August 1954, Hurricane Carol also caused a severe tidal surge (References 2 and 3). The 1938 and 1954 storms had recurrence intervals of 100 and 50 years, respectively.

Riverine flooding also occurs in Providence. In March 1968, the riverine flow of record occurred on both the Woonasquatucket and Moshassuck Rivers. Extensive flooding occurred on the Woonasquatucket River near Erickson Place, Valley Street, Amherst Street, and Eagle Street. The recurrence interval for this flood on the Woonasquatucket River at the U. S. Geological Survey (USGS) gaging station in Centerdale was estimated to be 35 years. Flooding on the Moshassuck River occurred near Canal and Mill Streets below the USGS gage and along Interstate 95. Gage records showed this flood to be a 38-year event on the Moshassuck River. Flooding resulting from this storm was also extensive on the West River. Areas adjacent to Charles Street were extensively flooded.

2.4 Flood Protection Measures

Subsequent to the floods of 1938 and 1954, a hurricane barrier was constructed at Fox Point where the Providence River empties into Narragansett Bay. This structure is equipped with large gates to prevent the inflow of hurricane tides and pumps to discharge the riverine flows downstream of the barrier. Appurtenant structures include gates at certain road underpasses, dikes, and the embankment of Interstate 95. These measures effectively eliminate the downtown area from hurricane-related flood hazards.

The Moshassuck River along Interstate 95 has an improved riprap channel in many areas. Construction of State Route 146 adjacent to the West River has resulted in an improved channel through this area. Recent channel clearing on the West River near Charles Street will also aid in flood hazard reduction.

During floods of a magnitude greater than 10 years, the West River overflows its banks in the vicinity of Charles Street and Amtrak. This flow is channelized into the railroad right-of-way, where it flows south to below Smith Street. A culvert has been installed just below Smith Street to divert this flow from the tracks to the Moshassuck River (Reference 4). The culvert is a drop inlet structure consisting of grating across the tracks which drops into a 19-foot-by-6-foot box culvert. The diverted flow then enters the Moshassuck River. The culvert is designed to act against the 100-year flood on the river. A crib wall on the western side of the tracks diverts flow onto the tracks and into the culvert rather than into the capital area.

Rising Sun Dam, Paragon Dam, Dyerville Dam, Manton Pond Dam, Geneva Pond Dam, Whipples Pond Dam, Upper Canada Pond Dam, and several unnamed dams are located within the corporate limits of Providence. These dams, however, do not provide any flood protection for the area.

3.0 ENGINEERING METHODS

For the flooding sources studied in detail in the community, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this study. Flood events of a magnitude which are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for flood plain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10, 2, 1, and 0.2 percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood which equals or exceeds the 100-year flood (1 percent chance of annual exceedence) in any 50-year period is approximately 40 percent (4 in 10), and, for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish the peak discharge-frequency and peak elevation-frequency relationships for the flooding sources studied in detail affecting the community.

Peak discharge-frequency relationships for the Providence River, the Woonasquatucket River, and the Moshassuck River were based on stream gaging records at the USGS gage (No. 01114500) located in Centerdale on the Woonasquatucket River and at the USGS gage (No. 01114000) located in Providence on the Moshassuck River. The Woonasquatucket River gage has a recording period from 1941 to the present, while the Moshassuck River gage has a recording period from 1963 to the present. A log-Pearson Type III distribution of the annual peak flows of the rivers at the gages was calculated using the method recommended by the Water Resources Council (Reference 5).

The hydrology for the West River and Upper Canada Pond is based on flood flow equations developed by the USGS in cooperation with the Rhode Island Department of Transportation. The report entitled Flood Magnitude and Frequency of Small Rhode Island Streams was utilized for streams in Rhode Island with drainage areas less than 10 square miles (Reference 6). Multiple regression techniques were utilized to define the relationship between flood peaks based on records collected at a network of gaging stations maintained by the USGS and on a set of watershed basin characteristics.

A separate analysis was performed to consider the effects of the diversion conduit on the hydrology of the Moshassuck and West Rivers. During floods with a recurrence interval greater than 10 years, floodwaters from the West River flow out of the main channel at Charles Street and at the Amtrak tracks. Before the installation of the diversion conduit, flow was channelized along the railroad right-of-way to just below Smith Street where it flowed through the capital redevelopment area and into the Woonasquatucket River. Considerable ponding and inundation of the redevelopment area occurred. Therefore, as part of the redevelopment program, a diversion conduit has been built to divert the flow from the railroad tracks to the Moshassuck River (Reference 4). The conduit is a drop inlet structure in the track bed which will intercept the flow from the tracks. The conduit is designed to operate against a 100-year flood on the Moshassuck River.

Flood discharges were recomputed for the West River to account for the diversion down the railroad tracks. Discharges were decreased for the portion of the river downstream of Charles Street and the railroad tracks based on the amount of flow which could be expected to be diverted at a given flood elevation.

For the Moshassuck River, discharges below the point of entry of the diverted flow were increased to account for flows from the conduit. Discharges upstream of the conduit would not be affected.

It is not likely that the diversion conduit will affect peak discharges on the Woonasquatucket River. The concentration times of the river would be considerably longer than the concentration time for the flow from the railroad tracks. The peak flow from the tracks would enter the river before the river's flood peak occurs. Thus, diversion of the track flow would only slightly lower the peak discharge on the Woonasquatucket River, not enough to affect peak flood elevations.

Hydrologic information for the Pocasset River was obtained from the Flood Insurance Study for the City of Cranston (Reference 7). The discharge-frequency relationship was determined from methodology developed by the Soil Conservation Service (SCS), which analyzed anticipated rainfall and resulting runoff (Reference 8). The watershed for the Pocasset River was divided into areas of uniform characteristics. An analysis of slope, soils, vegetation, land use, and stream channels of these areas was made to compute composite runoff curve numbers, times of concentration, and travel times. Storage capacity and stage-discharge curves were computed for all significant reservoirs and natural storage areas. The 10-, 50-, 100-, and 500-year synthetic storms were then flood routed through the upstream area of the watershed using the SCS TR-20 computer program (Reference 9). The program computes surface runoff resulting from synthetic or natural rainstorms. It takes into account conditions

affecting runoff and routes flow through stream channels and reservoirs. The program combines the routed hydrograph with those from other tributaries and computes peak discharge, time of occurrence, and the water-surface elevation at selected cross sections.

A summary of drainage area-peak discharge relationships for the riverine streams studied by detailed methods is shown in Table 1, "Summary of Discharges."

TABLE 1 - SUMMARY OF DISCHARGES

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-YEAR	50-YEAR	100-YEAR	500-YEAR
PROVIDENCE RIVER					
At Fox Point Hurricane Barrier	76.1	3,500	5,700	6,900	10,200
At Crawford Square	74.5	3,400	5,500	6,600	9,850
WOONASQUATUCKET RIVER					
Above the confluence of the Moshassuck River	51.1	1,800	2,900	3,500	5,200
At Atwells Avenue	47.8	1,590	2,570	3,090	4,600
At the upstream corporate limits	43.8	1,350	2,170	2,600	3,900
MOSHASSUCK RIVER					
At its confluence with the Woonasquatucket River	23.4	1,770	3,275	4,210	6,790
Above the diversion conduit	22.9	1,745	2,755	3,290	4,850
Above the confluence of the West River	11.4	830	1,310	1,560	2,300
At the upstream corporate limits	10.1	730	1,150	1,370	2,020
WEST RIVER					
At its confluence with the Moshassuck River	11.1	876	1,050	1,150	1,200
Upstream of Amtrak	10.7	822	1,150	1,350	1,700
Upstream side of Charles Street	9.5	822	1,435	1,866	2,930
Upstream of confluence of Upper Canada Pond Brook	7.8	706	1,246	1,642	2,600
Upstream side of Whipples Pond Dam	7.2	672	1,190	1,575	2,500

TABLE 1 - SUMMARY OF DISCHARGES - continued

<u>FLOODING SOURCE AND LOCATION</u>	<u>DRAINAGE AREA</u> (sq. miles)	<u>PEAK DISCHARGES (cfs)</u>			
		<u>10-YEAR</u>	<u>50-YEAR</u>	<u>100-YEAR</u>	<u>500-YEAR</u>
UPPER CANADA POND BROOK					
At its confluence with the West River	2.2	124	248	340	680
POCASSET RIVER					
Upstream of Print Works Pond Dam	18.9	2,334	4,244	5,330	7,120

Elevation-frequency relationships for the Providence River and the Seekonk River were determined by analyzing the tidal gage records and historic high-water mark data for Narragansett Bay, the Sakonnet River, and Rhode Island Sound (References 10, 11, 12, and 13). Tide gages are maintained by the National Oceanic and Atmospheric Administration in Narragansett Bay at Newport and at Providence. At points where reliable high-water records were available, stage correlation analyses were performed to develop profiles for floods of the selected recurrence interval.

Historic flood elevations are shown in Table 2 (References 2, 3, 10, 11, 12, 14, and 15). For the Providence tide gage, an elevation-frequency relationship was determined using a Pearson Type III distribution on the gage record. Elevations recorded in the 1600s were not used, although the COE used these floodmarks in their 1964 gage analysis. A stage-frequency curve was revised from the COE 1964 analysis because the 1964 curve used elevation 10.8 at Newport for the 1938 hurricane rather than the recorded 12.5.

TABLE 2 - HIGH-WATER MARK ELEVATIONS

LOCATION	HURRICANE September 21, 1938	HURRICANE CAROL August 31, 1954	HURRICANE September 14, 1944
	(feet - NGVD)	(feet - NGVD)	(feet - NGVD)
<u>Narragansett Bay</u>			
Newport			
Bailey Beach	13.5	--	--
Price Neck	15.0	11.0	--
Brenton Point	19.9, 18.6	--	--
Newport Harbor	11.4	--	--
USC&GS Tidal Gage	12.8	9.8	6.6

TABLE 2 - HIGH-WATER MARK ELEVATIONS - continued

LOCATION	HURRICANE September 21, 1938 (feet - NGVD)	HURRICANE CAROL August 31, 1954 (feet - NGVD)	HURRICANE September 14, 1944 (feet - NGVD)
<u>Narragansett Bay</u>			
Middletown			
Coddington Cove	--	10.5	--
Portsmouth			
South End			
Providence Island	12.3	11.0	--
Melville	12.4	11.4	--
Homestead	14.2	12.0	--
Bristol			
Bristol Point	--	13.4	--
Bristol Harbor	13.2, 14.0	12.5, 13.0	--
Warren			
Warren River Mouth	14.6	13.2	--
Barrington			
Rumstick Neck	15.1	--	--
Barrington Beach	15.5	15.0	--
Nayatt Point	15.4	15.1	--
Bullock Cove	15.2	14.5	--
East Providence			
Bullock Point	15.8	14.8	--
Crescent Park	16.1	--	--
Squantum Point	15.9	16.2	--
Providence			
Seekonk River	16.1	14.9	--
Point St. Bridge	16.6	15.3	--
USC&GS Tide Gage	15.8	14.8	10.0
<u>Sakonnet River</u>			
Little Compton			
Breakwater Point	13.8	10.7	--

TABLE 2 - HIGH-WATER MARK ELEVATIONS - continued

LOCATION	HURRICANE	HURRICANE CAROL	HURRICANE
	September 21, 1938 (feet - NGVD)	August 31, 1954 (feet - NGVD)	September 14, 1944 (feet - NGVD)
<u>Sakonnet River</u>			
Portsmouth			
Sandy Point	--	11.8	--
McCurry Point	--	11.3	--
Island Park	15.3	14.4	--
Railroad Bridge	15.6	--	--
Common Fence Point	14.2	12.0	--
 Warren River			
Laurel Park	--	14.0	--
Kickamuit River	13.2	13.5	--
 Fall River			
USC&GS Tide Gage	13.8	13.4	9.3

The stillwater elevations for the 10-, 50-, 100-, and 500-year floods have been determined for the Providence River and the Seekonk River and are summarized in Table 3.

TABLE 3 - SUMMARY OF STILLWATER ELEVATIONS

FLOODING SOURCE AND LOCATION	ELEVATION (feet)			
	10-YEAR	50-YEAR	100-YEAR	500-YEAR
PROVIDENCE RIVER				
Entire shoreline within community	10.2	14.2	16.0	20.0
SEEKONK RIVER				
Entire shoreline within community	10.2	14.2	16.0	20.0

The analyses reported in this study reflect the stillwater elevations due to tidal and wind setup effects. The effects of wave action were also considered in the determination of flood hazard areas. Coastal

structures that are located above stillwater flood elevations can still be severely damaged by wave runup, wave-induced erosion, and wave-borne debris. The extent of wave runup past stillwater levels depends greatly on the wave conditions and local topography.

Wave heights and corresponding wave crest elevations were determined using the National Academy of Sciences (NAS) methodology (Reference 16). The wave runup was determined using the methodology developed by Stone and Webster Engineering Corporation for FEMA (Reference 17).

3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding from the riverine sources studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals.

Cross sections for the backwater analyses were determined by field survey along the stream channel. Cross sections were located at close intervals above and below bridges, culverts, and dams in order to compute the significant backwater effects of these structures. In addition, cross sections were taken between hydraulic controls whenever warranted by topographic changes. All bridges, culverts, and dams were surveyed to obtain elevation data and structural geometry.

Locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles (Exhibit 1). For stream segments for which a floodway was computed (Section 4.2), selected cross section locations are also shown on the Flood Boundary and Floodway Map (Exhibit 2).

Water-surface elevations of floods of the selected recurrence intervals for the Providence River, the Woonasquatucket River, the Moshassuck River, the West River, and Upper Canada Pond Brook were computed using the COE HEC-2 step-backwater computer program (Reference 18). Water-surface elevations for the Pocasset River were computed using the SCS WSP-2 computer program (Reference 19). Flood profiles were drawn showing computed water-surface elevations for floods of the selected recurrence intervals.

Starting water-surface elevations for the Providence River were based on a review of the Fox Point Hurricane Barrier design memoranda, operation manual, and Providence tide gage records. Starting water-surface elevations for the Woonasquatucket River and the Moshassuck River were based on the backwater profiles of the Providence River. Starting water-surface elevations for the West River and Upper Canada Pond Brook were determined using normal depth calculations. Starting water-surface elevations for the Pocasset River were taken from a SCS Flood Hazard Analyses report (Reference 20).

Roughness coefficients (Manning's "n") used in the hydraulic computations were assigned on the basis of field inspection of channel and overbank areas and photographs. The channel "n" and overbank "n" values for the riverine streams studied by detailed methods are shown in the following tabulation:

<u>Stream</u>	<u>Channel "n"</u>	<u>Overbank "n"</u>
Providence River	0.025-0.030	0.060-0.090
Woonasquatucket River	0.025-0.030	0.060-0.090
Moshassuck River	0.015-0.030	0.050-0.100
West River	0.030-0.050	0.030-0.080
Upper Canada Pond Brook	0.020-0.060	0.040-0.080
Pocasset River	0.035-0.050	0.040-0.085

Normal depth calculations were used to determine the shallow flooding area along Antrak from 900 feet north of Charles Street to 50 feet south of Smith Street. A ponding area was determined south of the intersection of Charles Street and Admiral Street.

The hydraulic analyses for this study were based on unobstructed flow. The flood elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

Hydraulic analyses, considering storm characteristics and the shoreline and bathymetric characteristics of the tidal flooding sources studied, were carried out to provide estimates of the elevations of floods of the selected recurrence intervals along each of these shorelines.

Areas of coastline subject to significant wave attack are referred to as coastal high hazard zones. The COE has established the 3-foot breaking wave as the criterion for identifying the limit of coastal high hazard zones (Reference 13). The 3-foot wave has been determined as the minimum size wave capable of causing major damage to conventional wood frame or brick veneer structures.

A wave height analysis was performed to determine wave heights and corresponding wave crest elevations for the areas inundated by the tidal flooding. A wave runup analysis was performed to determine the height and extent of runup beyond the limit of tidal inundation. The results of these analyses were combined into a wave envelope, which was constructed by extending the maximum wave runup elevation seaward to its intersection with the wave crest profile.

The methodology for analyzing wave heights and corresponding wave crest elevations was developed by the NAS (Reference 16). The NAS methodology is based on three major concepts.

First, a storm surge on the open coast is accompanied by waves. The maximum height of these waves is related to the depth of water by the following equation:

$$H_b = 0.78d$$

where H_b is the crest to trough height of the maximum or breaking wave and d is the stillwater depth. The elevation of the crest of an unimpeded wave is determined using the equation:

$$Z_w = S_* + 0.7H_* = S_* + 0.55d$$

where Z_w is the wave crest elevation, S_* is the stillwater elevation at the site, and H_* is the wave height at the site. The 0.7 coefficient is the portion of the wave height which reaches above the stillwater elevation. H_b is the upper limit for H_* .

The second major concept is that the breaking wave height may be diminished by dissipation of energy by natural or man-made obstructions. The wave height transmitted past a given obstruction is determined by the following equation:

$$H_t = BH_i$$

where H_t is the transmitted wave height, H_i is the incident wave height, and B is a transmission coefficient ranging from 0.0 to 1.0. The coefficient is a function of the physical characteristics of the obstruction. Equations have been developed by the NAS to determine B for vegetation, buildings, natural barriers such as dunes, and man-made barriers such as breakwaters and seawalls (Reference 16).

The third concept deals with unimpeded reaches between obstructions. New wave generation can result from wind action. This added energy is related to distance and mean depth over the unimpeded reach.

The methodology for analyzing wave runup was developed by Stone and Webster Engineering Corporation (Reference 17). The wave runup computer program operates using an ensemble of deepwater wave heights, H_1 , the stillwater elevation, S_* , a wave period, T_s , and beach slope, m . For much of the Providence coastline, it was determined that deepwater wave heights and the associated wave period will not be sufficient to cause runup over 2 feet above the stillwater level. Runup calculations were performed for the south facing coastline of Fields Point. However, for this coastline, the slopes are too flat for wave runup to be a significant flood hazard.

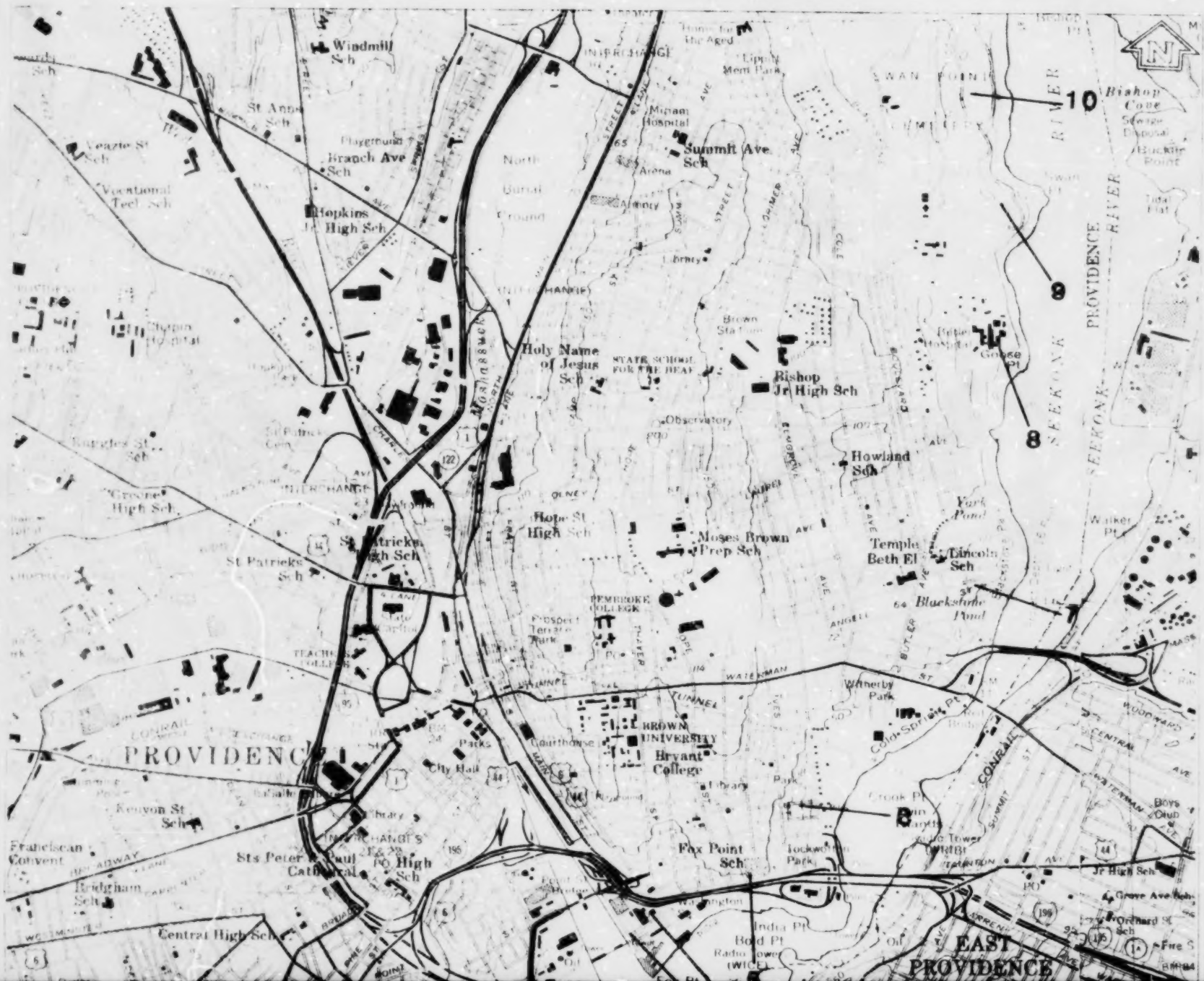
These concepts and equations were used to compute wave envelope elevations associated with the 100-year storm surge. Accurate topographic, land-use, and land cover data are required for the coastal analyses. Maps of the study area, at a scale of 1:960 with a contour interval of 2 feet were used for the topographic data (Reference 21). Depths below mean low water were determined from National Ocean Survey Nautical Charts (Reference 22). The land-use and land cover data were obtained from aerial photographs (Reference 23).

Wave heights and wave runup were computed along transects which were located perpendicular to the average mean shoreline. The transects were located with consideration given to the physical and cultural characteristics of the land so that they would closely represent conditions in their locality. Transects were spaced close together in areas of complex topography and dense development. In areas having more uniform characteristics, the transects were spaced at larger intervals. It was also necessary to locate transects in areas where unique flooding existed and in areas where computed wave heights varied significantly between adjacent transects. Figure 2, "Transect Location Map," illustrates the location of the transects for the community.

The maps used in the wave analyses were supplied by the city (Reference 21). These maps were compiled from aerial photography dated 1966; since that time, several areas along the shoreline have changed. In the Fields Point area, a park was developed. Engineering plans for this area were obtained and used for the wave analyses. A field survey was carried out for Transect 1 because the area had changed significantly.

Along each transect, wave envelope elevations were computed considering the combined effects of changes in ground elevation, vegetation, and physical features. Between transects, elevations were interpolated using the topographic maps, land-use and land cover data, and engineering judgment to determine the areal extent of flooding. The results of the calculations are accurate until local topography, vegetation, or cultural development within the community undergo any major changes. Selected beach transects with stillwater elevations for the 10- and 100-year recurrence intervals and wave envelope profiles for the 100-year recurrence interval are shown on the Coastal Profiles (Exhibit 3).

All elevations used in this study are referenced to the National Geodetic Vertical Datum of 1929 (NGVD). This elevation is 2.35 feet below the City of Providence datum of Mean High Water. Elevation reference marks used are shown on the maps.



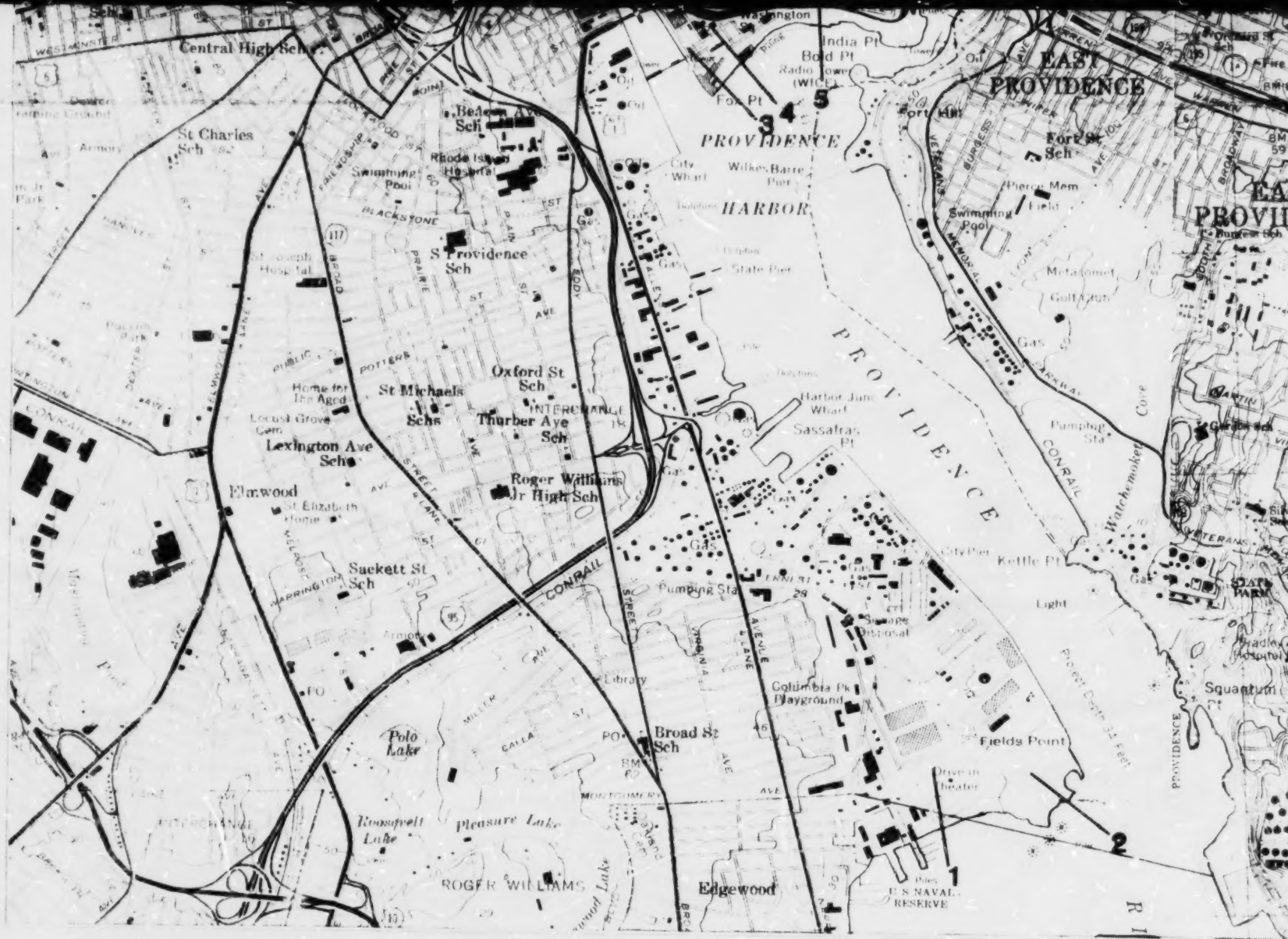


FIGURE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVIDENCE, RI
(PROVIDENCE CO.)

APPROXIMATE SCALE

2000 0 2000 4000 6000 FEET

TRANSECT LOCATION MAP

17A

4.0 FLOOD PLAIN MANAGEMENT APPLICATIONS

The National Flood Insurance Program encourages State and local governments to adopt sound flood plain management programs. Therefore, each Flood Insurance Study produces maps designed to assist communities in developing flood plain management measures.

4.1 Flood Boundaries

To provide a national standard without regional discrimination, the 1 percent annual chance (100-year) flood has been adopted by FEMA as the base flood for flood plain management purposes. The 0.2 percent annual chance (500-year) flood is employed to indicate additional areas of flood risk in the community. For each riverine stream studied in detail, the 100- and 500-year flood plain boundaries have been delineated using the flood elevations determined at each cross section. Between cross sections, the boundaries were interpolated using topographic maps (Reference 21).

For tidal areas without wave action, the 100-year and 500-year boundaries were delineated using the topographic maps referenced above (Reference 21). For the tidal areas with wave action, the flood boundaries were delineated using the elevations determined at each transect; between transects, the boundaries were interpolated using engineering judgment, land-cover data, and the topographic maps referenced above. The 100-year flood plain was divided into whole-foot elevation zones based on the average wave envelope elevation in that zone. Where the map scale did not permit these zones to be delineated at one foot intervals, larger increments were used.

For the areas studied by approximate methods, the boundary of the 100-year flood was delineated using the Flood Hazard Boundary Map for Providence (Reference 24).

The 100- and 500-year flood plain boundaries are shown on the Flood Boundary and Floodway Map (Exhibit 2). In cases where the 100- and 500-year flood plain boundaries are close together, only the 100-year flood plain boundary has been shown. Small areas within the flood plain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

4.2 Floodways

Encroachment on flood plains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of flood plain management involves balancing the economic gain from flood plain development against the resulting increase in flood hazard. For purposes of the National Flood Insurance Program, a floodway is used as a

tool to assist local communities in this aspect of flood plain management. Under this concept, the area of the 100-year flood plain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent flood plain areas, that must be kept free of encroachment so that the 100-year flood can be carried without substantial increases in flood heights. Minimum federal standards limit such increases to 1.0 foot, provided that hazardous velocities are not produced. The floodways in this study are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway studies.

The floodways presented in this study were computed on the basis of equal conveyance reduction from each side of the flood plain. The results of these computations are tabulated at selected cross sections for each stream segment for which a floodway is computed (Table 4).

As shown on the Flood Boundary and Floodway Map (Exhibit 2), the floodway boundaries were computed at cross sections. Between cross sections, the boundaries were interpolated. In cases where the floodway and 100-year flood plain boundaries are either close together or collinear, only the floodway boundary has been shown. A floodway could not be delineated on the Pocasset River because sufficient floodway information was not available from the Flood Insurance Study for Cranston, Rhode Island (Reference 7). Portions of the floodway widths for the Woonasquatucket River and the West River extend beyond the corporate limits.

The area between the floodway and 100-year flood plain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the flood plain that could be completely obstructed without increasing the water-surface elevation of the 100-year flood by more than 1.0 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to flood plain development are shown in Figure 3.

Near the mouths of streams studied in detail, floodway computations are made without regard to flood elevations on the receiving water body. Therefore, "Without Floodway" elevations presented in Table 4 for certain downstream cross sections of the West River and Upper Canada Pond Brook are lower than the regulatory flood elevations in that area, which must take into account the 100-year flooding due to backwater from other sources.

5.0 INSURANCE APPLICATION

To establish actuarial insurance rates, data from the engineering study must be transformed into flood insurance criteria. This process includes the determination of reaches, Flood Hazard Factors, and flood insurance zone designations for each flooding source studied in detail in the City of Providence.

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FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE ¹	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY	INCREASE
Providence River								
A	3,299	170	1,384	4.8	5.1	5.1	5.1	0.0
B	3,689	133	1,133	5.8	5.2	5.2	5.2	0.0
C	3,845	133	1,119	5.9	5.4	5.4	5.4	0.0
D	4,210	136	1,207	5.5	5.7	5.7	5.7	0.0
Woonasquatucket River								
E	4,832	106	1,007	3.5	6.3	6.3	6.3	0.0
F	5,017	102	952	3.7	6.3	6.3	6.3	0.0
G	5,453	100	872	4.0	6.4	6.4	6.4	0.0
H	6,006	100	888	3.9	6.6	6.6	6.6	0.0
I	6,507	77	728	4.8	6.8	6.8	6.8	0.0
J	7,668	114	866	4.0	7.5	7.5	7.5	0.0
K	8,122	117	873	4.0	7.8	7.8	7.8	0.0
L	8,368	113	748	4.7	8.0	8.0	8.0	0.0
M	9,040	104	673	5.2	8.5	8.5	8.5	0.0
N	9,632	112	679	5.2	9.1	9.1	9.1	0.0
O	10,184	74	645	5.4	9.9	9.9	9.9	0.0
P	10,355	82	770	4.5	10.9	10.9	11.1	0.2
Q	11,712	70	708	4.4	12.8	12.8	13.1	0.3
R	12,370	80	647	4.8	14.1	14.1	14.3	0.2
S	12,872	70	634	4.9	15.8	15.8	16.7	0.9
T	14,042	140	1,067	2.9	17.1	17.1	18.1	1.0

¹Feet above Fox Point Hurricane Barrier

TABLE 4

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVIDENCE, RI
(PROVIDENCE CO.)

FLOODWAY DATA**PROVIDENCE RIVER AND WOONASQUATUCKET RIVER**

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE ¹	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY	INCREASE
Woonasquatucket River (continued)								
U	14,590	146	737	4.2	17.3	17.3	18.2	0.9
V	15,295	116	1,102	2.8	19.2	19.2	19.9	0.7
W	15,457	109	495	6.2	20.2	20.2	20.6	0.4
X	16,293	68	388	8.0	22.5	22.5	22.5	0.0
Y	16,677	93	703	4.4	24.1	24.1	24.1	0.0
Z	17,455	41	282	11.0	25.8	25.8	25.9	0.1
AA	17,818	50	374	8.3	28.4	28.4	28.5	0.1
AB	18,198	37	436	7.1	30.6	30.6	30.6	0.0
AC	18,404	65	675	4.6	33.1	33.1	33.2	0.1
AD	18,638	48	617	5.0	35.4	35.4	35.5	0.1
AE	19,048	54	665	4.6	36.1	36.1	36.1	0.0
AF	19,267	118	1,338	2.3	36.4	36.4	36.5	0.1
AG	19,377	165	1,054	2.9	36.9	36.9	37.3	0.4
AH	20,145	95	393	7.9	37.1	37.1	37.4	0.3
AI	20,969	64	368	8.4	40.2	40.2	40.3	0.1
AJ	21,215	85	514	6.0	40.7	40.7	41.5	0.8
AK	21,867	142	946	3.3	41.8	41.8	42.3	0.5
AL	22,199	62	467	6.6	41.8	41.8	42.3	0.5
AM	23,030	67	267	11.6	44.2	44.2	44.2	0.0
AN	23,491	113	352	7.9	48.2	48.2	48.2	0.0
AO	24,324	110	440	6.3	50.9	50.9	51.3	0.4

¹Feet above Fox Point Hurricane Barrier

²This width extends beyond corporate limits

TABLE 4

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVIDENCE, RI
(PROVIDENCE CO.)

FLOODWAY DATA

WOONASQUATUCKET RIVER

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY	INCREASE
Woonasquatucket River (continued)								
AP	25,537 ¹	149 ³	825	3.4	52.4	52.4	53.3	0.9
AQ	26,023 ¹	199 ³	571	4.9	55.9	55.9	55.9	0.0
AR	27,535 ¹	52 ³	339	8.2	59.4	59.4	59.4	0.0
AS	28,501 ¹	54 ³	331	7.8	62.1	62.1	62.1	0.0
AT	29,563 ¹	145 ³	684	3.8	64.5	64.5	64.6	0.1
AU	30,296 ¹	181 ³	1,210	2.1	68.8	68.8	68.8	0.0
Moshassuck River								
A	0 ²	63	539	7.8	6.0	6.0	6.0	0.0
B	350 ²	46	421	10.0	7.1	7.1	7.1	0.0
C	859 ²	45	429	9.8	8.4	8.4	8.4	0.0
D	1,252 ²	44	465	9.1	10.5	10.5	10.5	0.0
E	1,701 ²	32	356	11.8	11.5	11.5	11.5	0.0
F	2,341 ²	34	361	9.3	13.8	13.8	13.8	0.0
G	2,793 ²	42	388	8.5	21.8	21.8	21.8	0.0
H	3,145 ²	30	362	9.1	22.3	22.3	22.7	0.4
I	3,818 ²	71	775	4.2	28.2	28.2	28.5	0.3
J	4,821 ²	85	766	4.3	28.5	28.5	28.9	0.4
K	5,450 ²	89	764	4.3	29.0	29.0	29.0	0.0
L	6,186 ²	52	513	6.4	29.1	29.1	29.3	0.2

¹Feet above confluence with Fox Point Hurricane Barrier

²Feet above confluence with Woonasquatucket River

³This width extends beyond corporate limits

TABLE 4

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVIDENCE, RI
(PROVIDENCE CO.)

FLOODWAY DATA

22

WOONASQUATUCKET RIVER AND MOSHASSUCK RIVER

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY	INCREASE
Moshassuck River (continued)								
M	6,574 ¹	76	695	2.2	29.8	29.8	30.2	0.4
N	6,911 ¹	62	544	2.9	30.5	30.5	30.8	0.3
O	9,720 ¹	20	219	6.3	32.0	32.0	32.4	0.4
P	10,579 ¹	30	248	5.5	33.1	33.1	33.6	0.5
Q	11,414 ¹	70	534	2.6	34.2	34.2	35.0	0.8
R	12,085 ¹	47	325	4.2	34.4	34.4	35.2	0.8
West River								
A	20 ²	30	229	4.8	29.5	24.9 ³	25.8	0.9
B	790 ²	17	111	9.9	29.5	25.5 ³	26.3	0.8
C	910 ²	61	380	2.9	29.5	28.0 ³	28.6	0.6
D	1,280 ²	64	322	3.4	29.5	28.3 ³	29.1	0.8
E	1,518 ²	15	136	8.1	29.5	28.5 ³	29.3	0.8
F	1,662 ²	100	553	2.4	30.5	30.5	30.9	0.3
G	1,729 ²	29	230	5.9	31.5	31.5	31.5	0.0
H	2,046 ²	26	244	5.5	31.9	31.9	32.1	0.2
I	2,392 ²	26	238	5.7	32.3	32.3	32.5	0.2
J	3,300 ²	90	520	3.6	34.1	34.1	34.4	0.3
K	4,048 ²	160	777	2.4	34.3	34.3	34.7	0.4
L	5,034 ²	96	295	6.3	34.5	34.5	34.8	0.3
M	5,790 ²	98	481	3.4	38.4	38.4	38.5	0.1

¹Feet above confluence with Woonasquatucket River

²Feet above confluence with Moshassuck River

³Elevation computed without consideration of backwater from Moshassuck River

TABLE 4

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVIDENCE, RI
(PROVIDENCE CO.)

FLOODWAY DATA

MOSHASSUCK RIVER AND WEST RIVER

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE ¹	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
(FEET NGVD)								
West River (continued)								
N	6,860	223	1,111	1.5	40.8	40.8	41.3	0.5
O	7,145	34	306	5.4	40.8	40.8	41.3	0.5
P	7,218	109	314	5.2	41.8	41.8	42.5	0.7
Q	7,369	150	553	3.0	42.3	42.3	43.2	0.9
R	7,437	172	593	2.8	42.5	42.5	43.4	0.9
S	7,523	198	518	3.2	42.9	42.9	43.5	0.6
T	7,676	278	172	1.4	43.9	43.9	44.2	0.3
U	7,755	343	912	1.8	43.9	43.9	44.2	0.3
V	7,824	393	1,059	1.6	44.0	44.0	44.3	0.3
W	8,045	344	726	2.3	44.3	44.3	44.5	0.2
X	8,714	34	171	9.6	47.5	47.5	48.0	0.5
Y	9,322	137	250	6.6	50.8	50.8	50.8	0.0
Z	9,983	140	301	5.4	57.2	57.2	57.7	0.5
AA	10,295	225	842	1.9	58.1	58.1	59.0	0.9
AB	10,876	65	389	4.2	60.0	60.0	60.8	0.8
AC	11,182	356	2,135	0.7	67.6	67.6	67.6	0.0
AD	12,136	35	138	11.4	68.2	68.2	68.2	0.0
AE	12,246	21	183	8.6	74.4	74.4	74.4	0.0
AF	12,783	459	2,909	0.5	77.6	77.6	77.6	0.0

¹Feet above confluence with Moshassuck River²This width extends beyond corporate limits

TABLE 4

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVIDENCE, RI
(PROVIDENCE CO.)

FLOODWAY DATA

WEST RIVER

24

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE ¹	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY	INCREASE
Upper Canada Pond Brook								
A	50	80	90	3.8	37.5	35.4 ²	35.4	0.0
B	310	22	66	5.2	37.5	35.9 ²	35.9	0.0
C	554	77	188	1.8	40.0	40.0	40.1	0.1
D	760	22	159	2.1	40.9	40.9	41.7	0.8
E	1,280	69	293	1.2	42.2	42.2	42.4	0.2
F	1,380	39	196	1.7	42.4	42.4	42.6	0.2
G	3,786	330	2,901	0.1	58.2	58.2	58.2	0.0

¹Feet above confluence with West River

²Elevation computed without consideration of backwater from West River

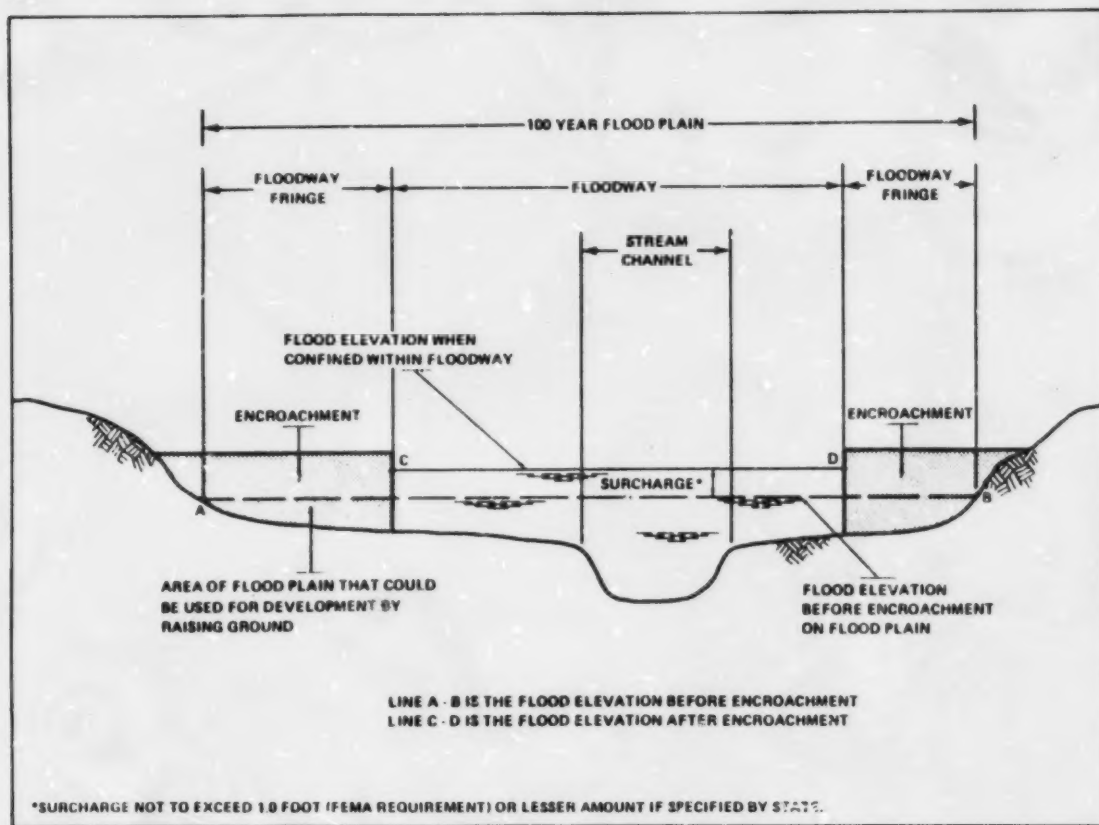
TABLE 4

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVIDENCE, RI
(PROVIDENCE CO.)

FLOODWAY DATA

UPPER CANADA POND BROOK



FLOODWAY SCHEMATIC

Figure 3

5.1 Reach Determinations

Reaches are defined as sections of flood plain that have relatively the same flood hazard, based on the average weighted difference in water-surface elevations between the 10- and 100-year floods. This difference may not have a variation greater than that indicated in the following tabulation for more than 20 percent of the reach:

<u>Average Difference Between 10- and 100-Year Floods</u>	<u>Variation</u>
Less than 2 feet	0.5 foot
2 to 7 feet	1.0 foot
7.1 to 12 feet	2.0 feet
More than 12 feet	3.0 feet

The locations of the reaches determined for the flooding sources of the City of Providence are shown on the Flood Profiles (Exhibit 1) and summarized in Table 5A.

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FLOODING SOURCE	PANEL ¹	ELEVATION DIFFERENCE ² BETWEEN 1.0% (100-YEAR) FLOOD AND			FHF	ZONE	BASE FLOOD ELEVATION ³ (NGVD)
		10% (10 YR.)	2% (50 YR.)	0.2% (500 YR.)			
Upper Canada Pond Brook Reach 1	02	-1.5	-0.6	+1.4	015	A3	Varies
Pocasset River Reach 1	07	-2.6	-0.8	+1.2	025	A5	75

¹Flood Insurance Rate Map Panel

²Weighted Average

³Rounded to the nearest foot - see map

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVIDENCE, RI
(PROVIDENCE CO.)

FLOOD INSURANCE ZONE DATA

UPPER CANADA POND BROOK AND POCASSET RIVER

27

FLOODING SOURCE	PANEL ¹	ELEVATION DIFFERENCE ² BETWEEN 1.0% (100-YEAR) FLOOD AND			FHF	ZONE	BASE FLOOD ELEVATION ³ (NGVD)
		10% (10 YR.)	2% (50 YR.)	0.2% (500 YR.)			
Providence River Reach 1	05	-0.7	-0.3	+1.3	005	A1	Varies
Woonasquatucket River							
Reach 1	05	-0.7	-0.3	+1.3	005	A1	Varies
Reach 2	04, 05	-2.3	-0.9	+3.2	025	A5	Varies
Reach 3	04	-5.3	-1.7	+3.3	055	A11	Varies
Reach 4	04	-2.5	-0.8	+2.8	025	A5	Varies
Moshassuck River							
Reach 1	05	-0.9	-0.5	+2.7	010	A2	Varies
Reach 2	05	-2.4	-1.4	+6.1	025	A5	Varies
Reach 3	03, 05	-5.4	-1.8	+4.7	055	A11	Varies
Reach 4	03	-4.2	-1.5	+7.9	040	A8	Varies

¹Flood Insurance Rate Map Panel

²Weighted Average

³Rounded to the nearest foot - see map

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVIDENCE, RI
(PROVIDENCE CO.)

FLOOD INSURANCE ZONE DATA

28

PROVIDENCE RIVER, WOONASQUATUCKET RIVER AND MOSHASSUCK RIVER

FLOODING SOURCE	PANEL ¹	ELEVATION DIFFERENCE ² BETWEEN 1.0% (100-YEAR) FLOOD AND			FHF	ZONE	BASE FLOOD ³ ELEVATION ³ (NGVD)
		10% (10 YR.)	2% (50 YR.)	0.2% (500 YR.)			
West River							
Reach 1	02	-1.3	-1.2	+3.0	015	A3	Varies
Reach 2	02	-1.9	-2.6	+2.5	020	A4	Varies
Reach 3	02	-2.8	-1.0	+2.6	030	A6	Varies
Reach 4	02	-1.0	-0.3	+0.6	010	A2	Varies
Reach 5	02	-1.8	-0.4	+1.2	020	A4	Varies
Reach 6	02	-1.6	-0.6	+1.5	015	A3	Varies
Along Amtrak from 900 feet north of Charles Street to 50 feet south of Smith Street	02,05	Shallow Flooding - Average Depth 2 Feet				A0	--
South of Inter- section of Charles Street and Admiral Street	02		Ponding Area		AH	25	

¹Flood Insurance Rate Map Panel

²Weighted Average

³Rounded to the nearest foot - see map

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVIDENCE, RI
(PROVIDENCE CO.)

FLOOD INSURANCE ZONE DATA

WEST RIVER

In areas where wave height and wave runup analyses were performed, reaches were determined for areas of the coastline, represented by a transect or group of transects, which have the same physical characteristics. For each transect the coastal high hazard zone (V zone) may be divided into two reaches to reflect those areas where wave runup is a dominant factor and those areas where wave runup does not dominate and elevations are determined by the wave height analysis. The reaches determined for the City of Providence are summarized in Table 5B.

TABLE 5B - FLOOD INSURANCE ZONE DATA

<u>Flooding Source</u>	<u>Stillwater Elevation</u>		<u>FHF</u>	<u>Zone</u>	<u>Base Flood Elevation (Feet NGVD) *</u>
	<u>10-Year</u>	<u>100-Year</u>			
Providence River	10.2	16.0	090	V18	18-21
			075	A15	16-18
			065	A13	16-18
			060	A12	16
Seekonk River	10.2	16.0	090	V18	18-20
			075	A15	16-18
			070	A14	16-18
			060	A12	16

*Due to map scale limitations, base flood elevations shown on the FIRM represent average elevations for the zones depicted.

5.2 Flood Hazard Factors

The Flood Hazard Factor (FHF) is used to establish relationships between depth and frequency of flooding in any reach. This relationship is then used with depth-damage relationships for various classes of structures to establish actuarial insurance rate tables.

The FHF for a reach is the average weighted difference between the 10- and 100-year flood water-surface elevations rounded to the nearest one-half foot, multiplied by 10, and shown as a three-digit code. For example, if the difference between water-surface elevations of the 10- and 100-year floods is 0.7 foot, the FHF is 005; if the difference is 1.4 feet, the FHF is 015; if the difference is 5.0 feet, the FHF is 050. When the difference between the 10- and 100-year flood water-surface elevations is greater than 10.0 feet, it is rounded to the nearest whole foot.

5.3 Flood Insurance Zones

Flood insurance zones and zone numbers are assigned based on the type of flood hazard and the FHF, respectively. A unique zone number is associated with each possible FHF, and varies from 1 for a FHF of 005 to a maximum of 30 for a FHF of 200 or greater.

Zone A: Special Flood Hazard Areas inundated by the 100-year flood, determined by approximate methods; no base flood elevations shown or FHFs determined.

Zone AO: Special Flood Hazard Areas inundated by types of 100-year shallow flooding where depths are between 1.0 and 3.0 feet; depths are shown but no FHFs are determined.

Zone AH: Special Flood Hazard Areas inundated by types of 100-year shallow flooding where depths are between 1.0 and 3.0 feet; base flood elevations are shown, but no FHFs are determined.

Zones A1, A2, A3, A4, A5, A6, A8, A11, A12, A13, A14, A15: Special Flood Hazard Areas inundated by the 100-year flood; with base flood elevations shown, and zones subdivided according to FHFs.

Zone V18: Special Flood Hazard Areas along coasts inundated by the 100-year flood that have additional velocity hazards associated with waves of 3-foot amplitude or greater; with base flood elevations shown, and zones subdivided according to FHFs.

Zone B: Areas between the Special Flood Hazard Areas and the limits of the 500-year flood; areas that are protected from the 100- or 500-year floods by dike, levee, or other water control structure; areas subject to certain types of 100-year shallow flooding where depths are less than 1.0 foot; and areas subject to 100-year flooding from sources with drainage areas less than 1 square mile. Zone B is not subdivided.

Zone C: Areas of minimal flooding; not subdivided.

Flood elevation differences, FHFs, flood insurance zones, and base flood elevations for the flooding sources studied in detail in the community are shown in Tables 5A and 5B.

5.4 Flood Insurance Rate Map Description

The Flood Insurance Rate Map for the City of Providence is, for insurance purposes, the principal result of the Flood Insurance Study. This map contains the official delineation of flood insurance zones and base flood elevations. Base flood elevation lines show the locations of the expected whole-foot water-surface elevation of the base (100-year) flood. The base flood elevations and zone numbers are used by insurance agents, in conjunction with structure elevations and characteristics, to assign actuarial insurance rates to structures and contents insured under the National Flood Insurance Program.

6.0 OTHER STUDIES

In 1965, hydraulic studies for the Woonasquatucket River and the Moshassuck River were published (References 25 and 26). The 100-year profile from this study agrees very closely with the 100-year profile for future land use published in 1965.

Flood Insurance Studies for the Towns of North Providence and Johnston have been completed (References 27 and 28). Profiles for the Woonasquatucket River were included in both studies; the North Providence study also included profiles for the West River and Upper Canada Pond Brook. Profiles for all floods on these streams in this study are consistently lower through all common areas. This difference is directly the result of the hydrologic analyses. Those studies utilized a rainfall-runoff computer model to estimate stream discharges, while this study utilized gage records and historic information to determine flood flows.

Flood Insurance Studies for the Cities of Cranston and East Providence have also been completed (References 7 and 29). The Cranston study does not agree with this study in the Fields Point area because of development in that area since the Cranston study was completed. The development affects the wave height analysis in this area. The East Providence study does not agree with this study along portions of the Seekonk River because of different wind exposure for the two cities.

The Flood Insurance Study for the City of Pawtucket is currently being prepared (Reference 30). The results of that study will be in exact agreement with the results of this study.

As a result of the capital area redevelopment, a diversion conduit was designed by DeLeuw Cather/Parsons to divert floodwaters which would normally flow from the West River down the railroad right-of-way to the redevelopment area. Flows are now diverted to the Moshassuck River. Maps and profiles were drawn showing the conduit in place (Reference 4). Design plans for the conduit were obtained for this study.

7.0 LOCATION OF DATA

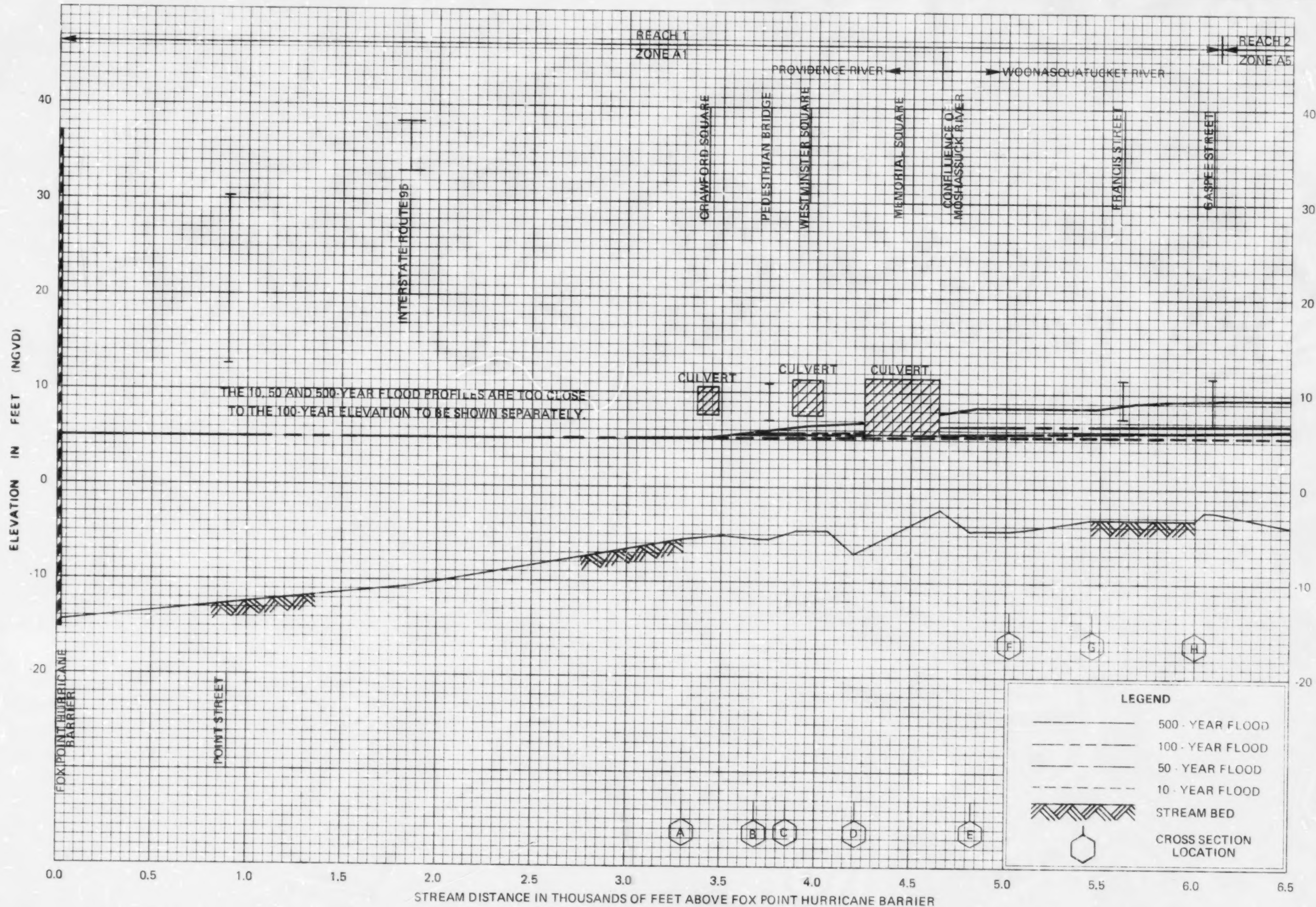
Information concerning the pertinent data used in preparation of this study can be obtained by contacting the Natural and Technological Hazards Division, Federal Emergency Management Agency, Regional Director, Region I Office, J. W. McCormack Post Office and Courthouse Building, Room 462, Boston, Massachusetts 02109.

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FLOOD PROFILES

PROVIDENCE RIVER AND WOONASQUATUCKET RIVER

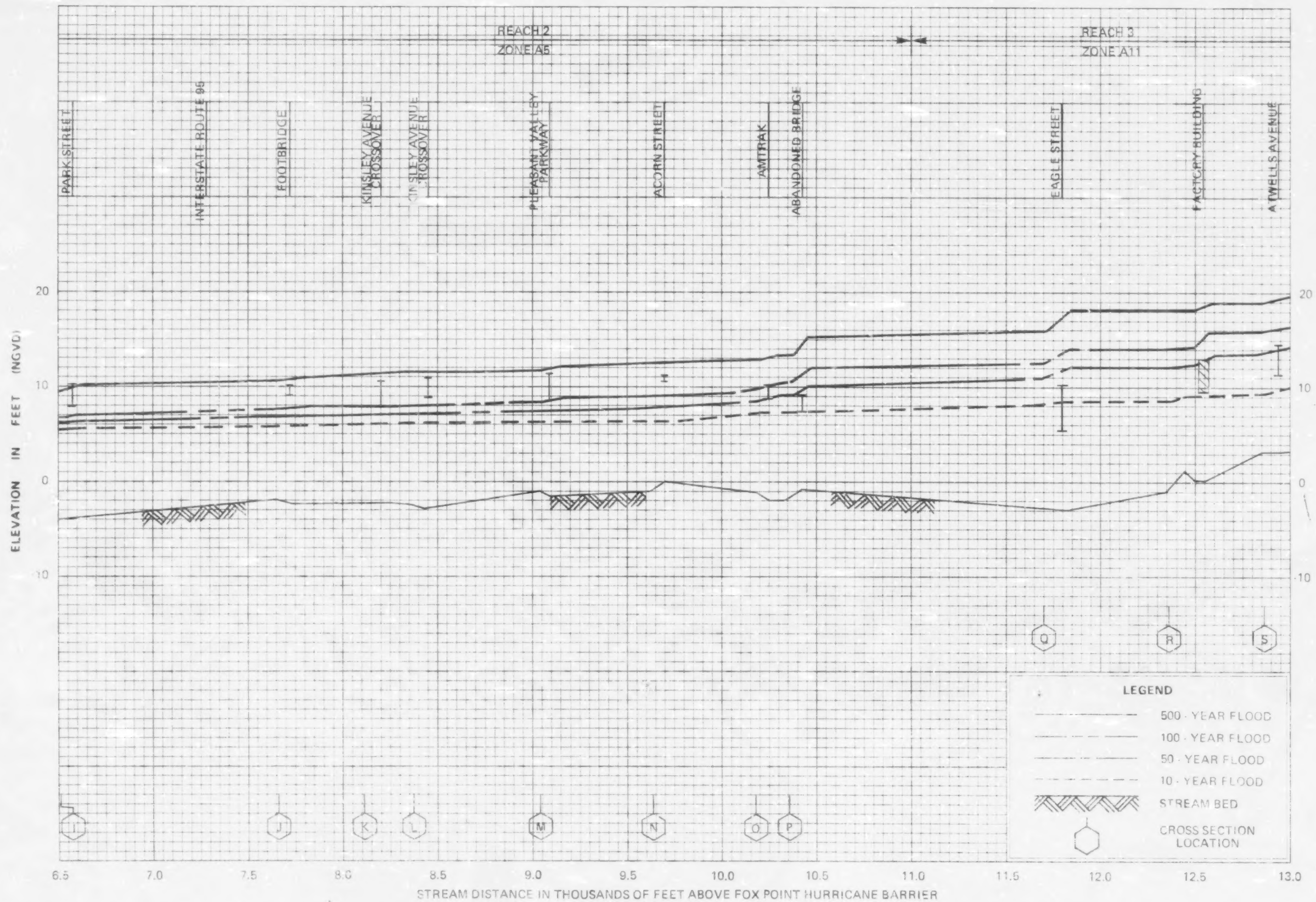
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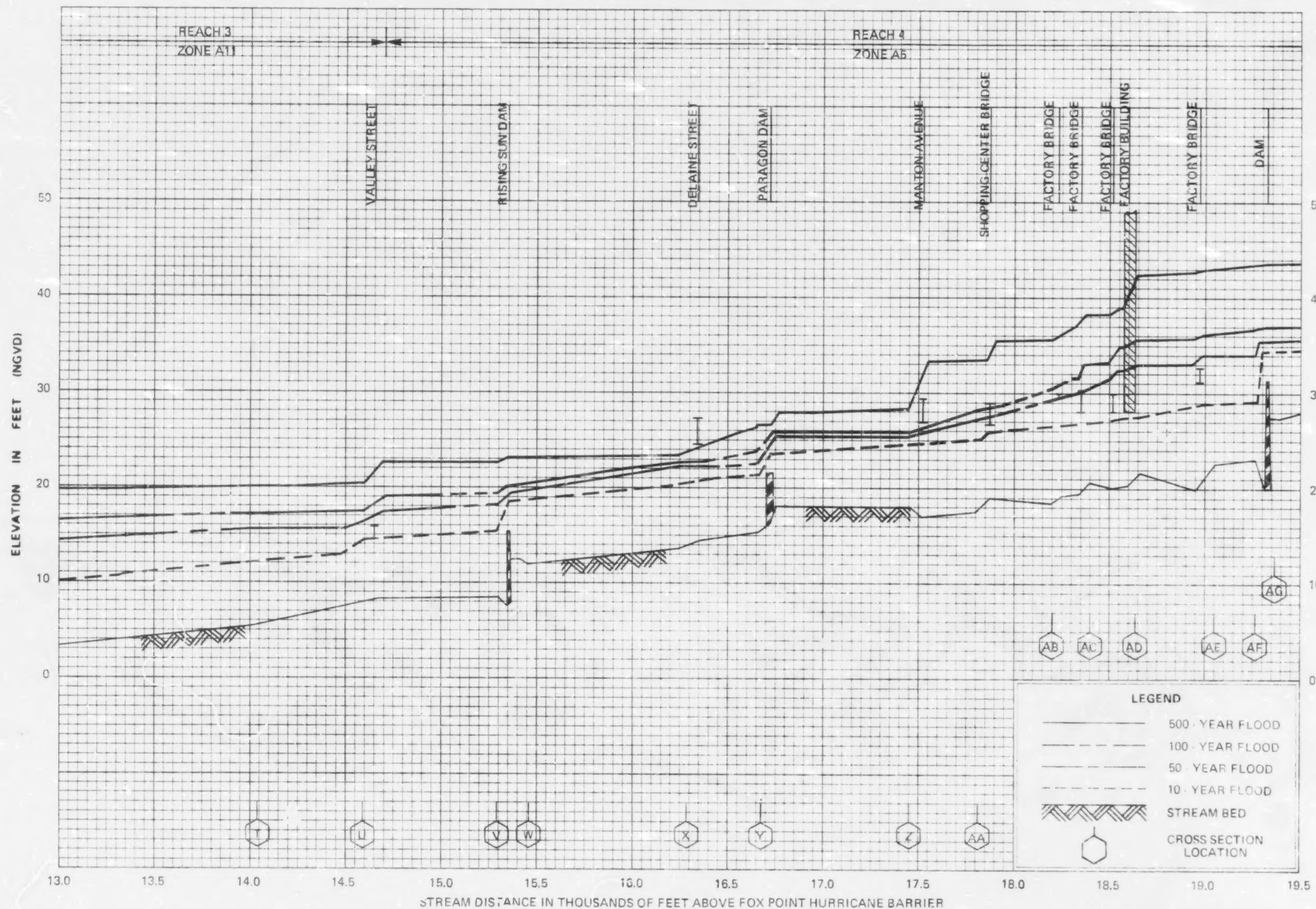
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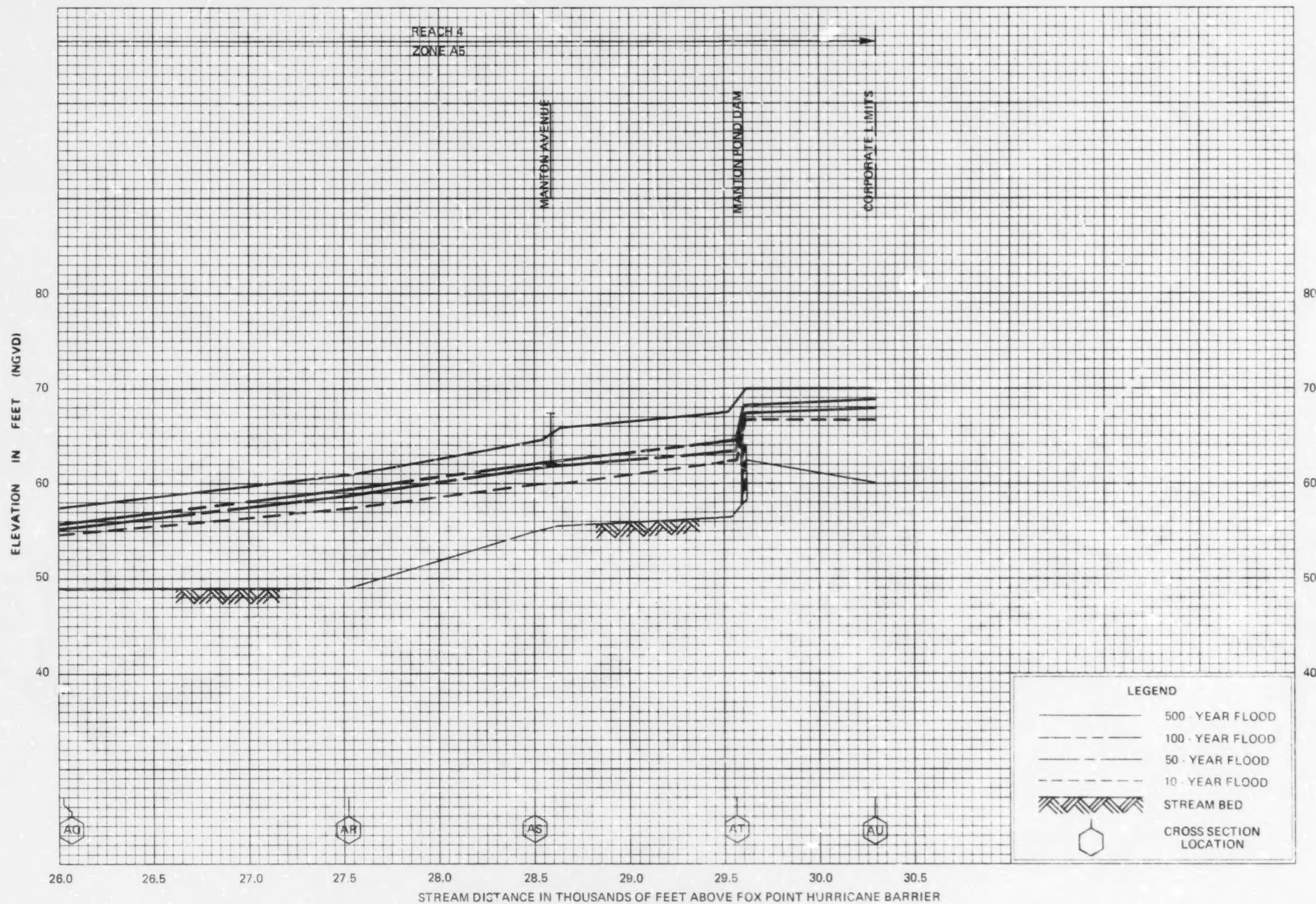
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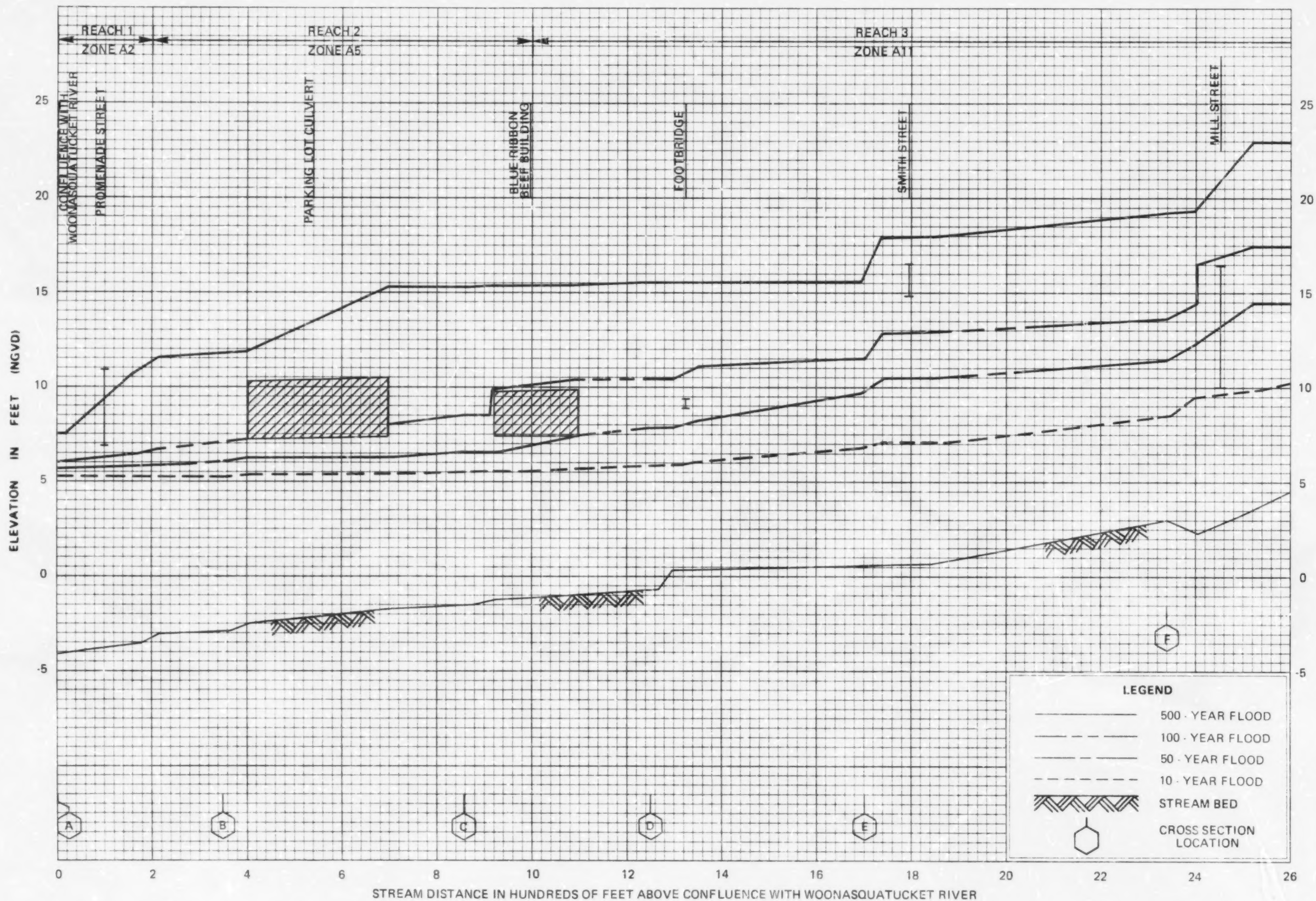


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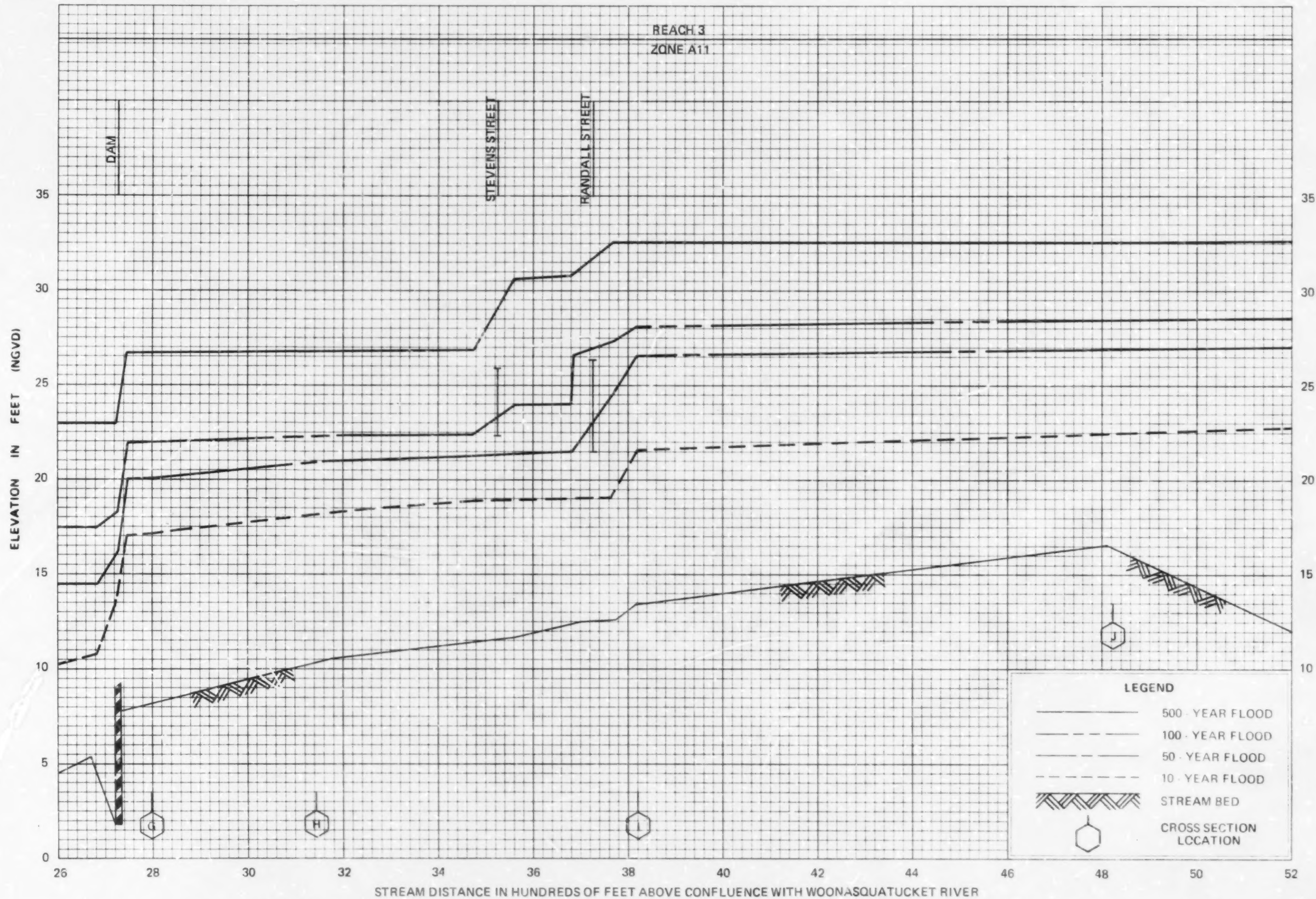
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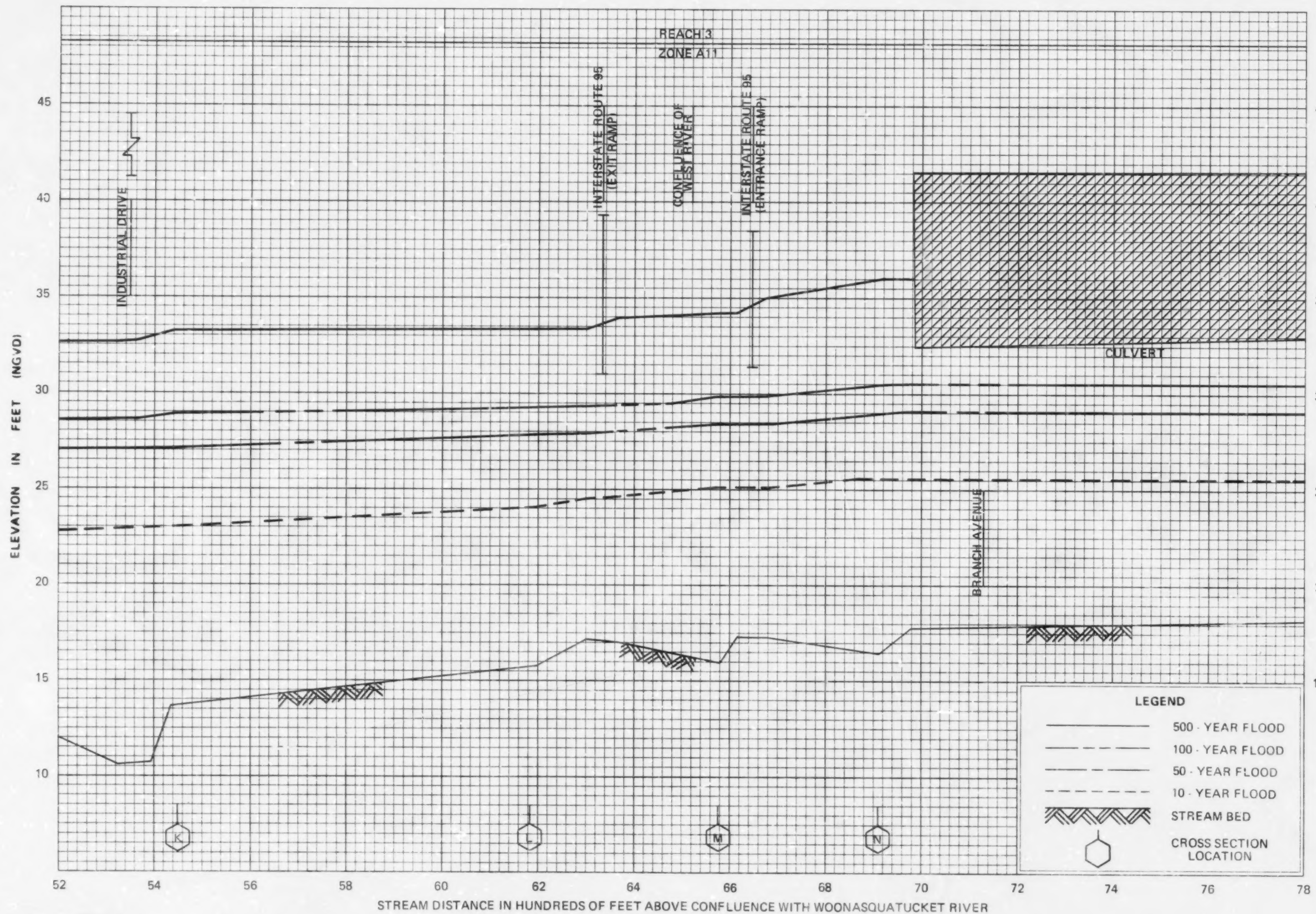
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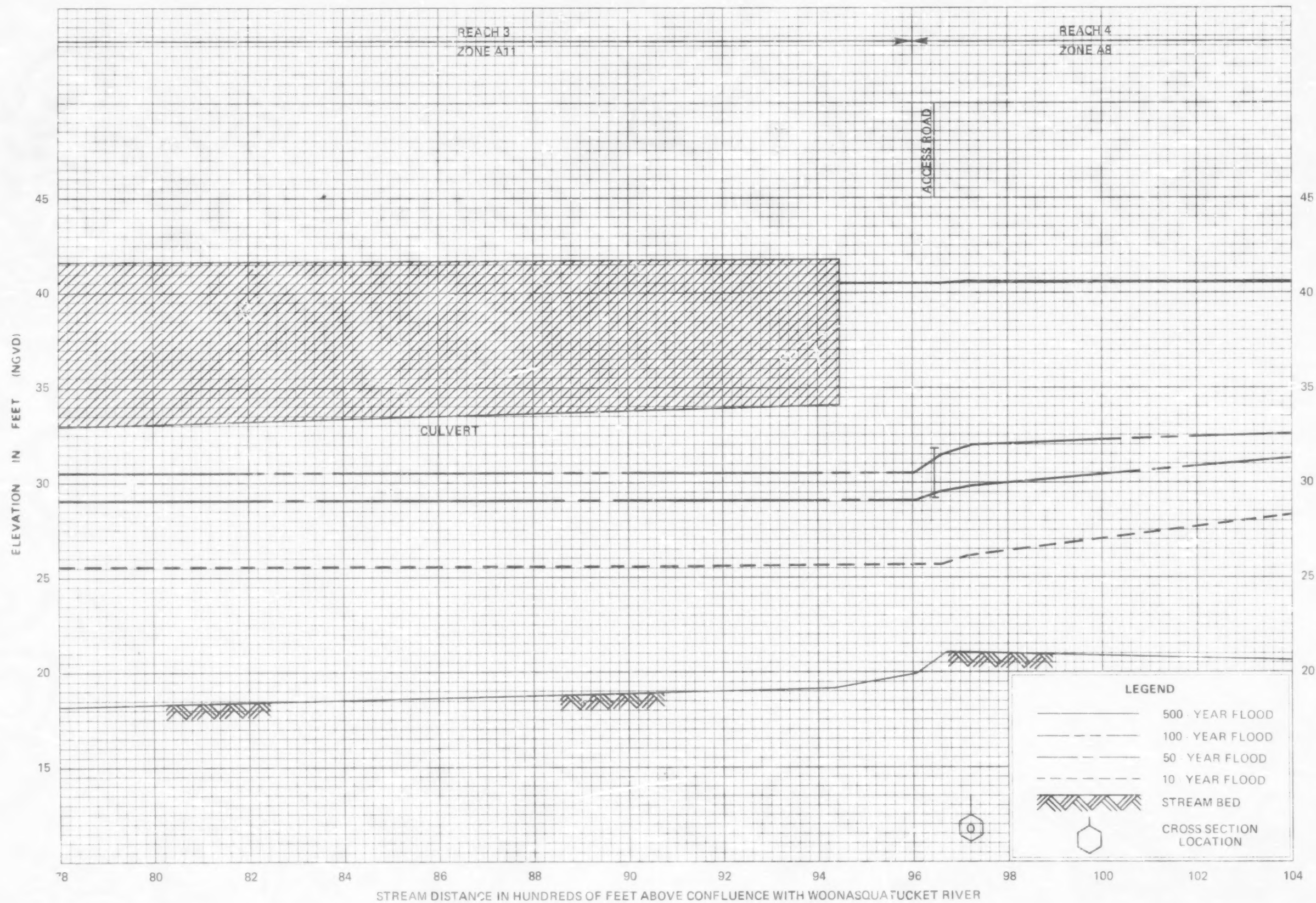
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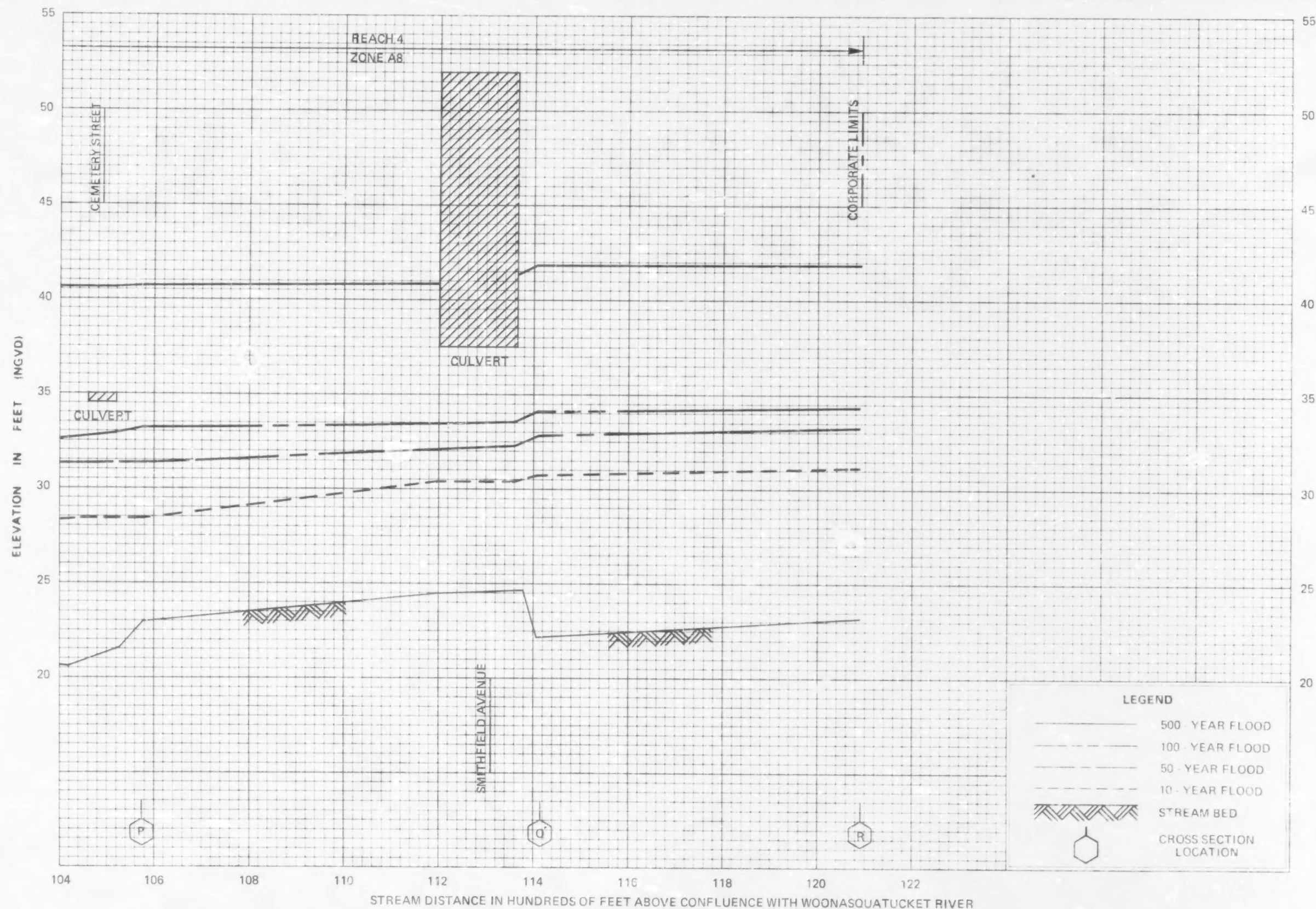


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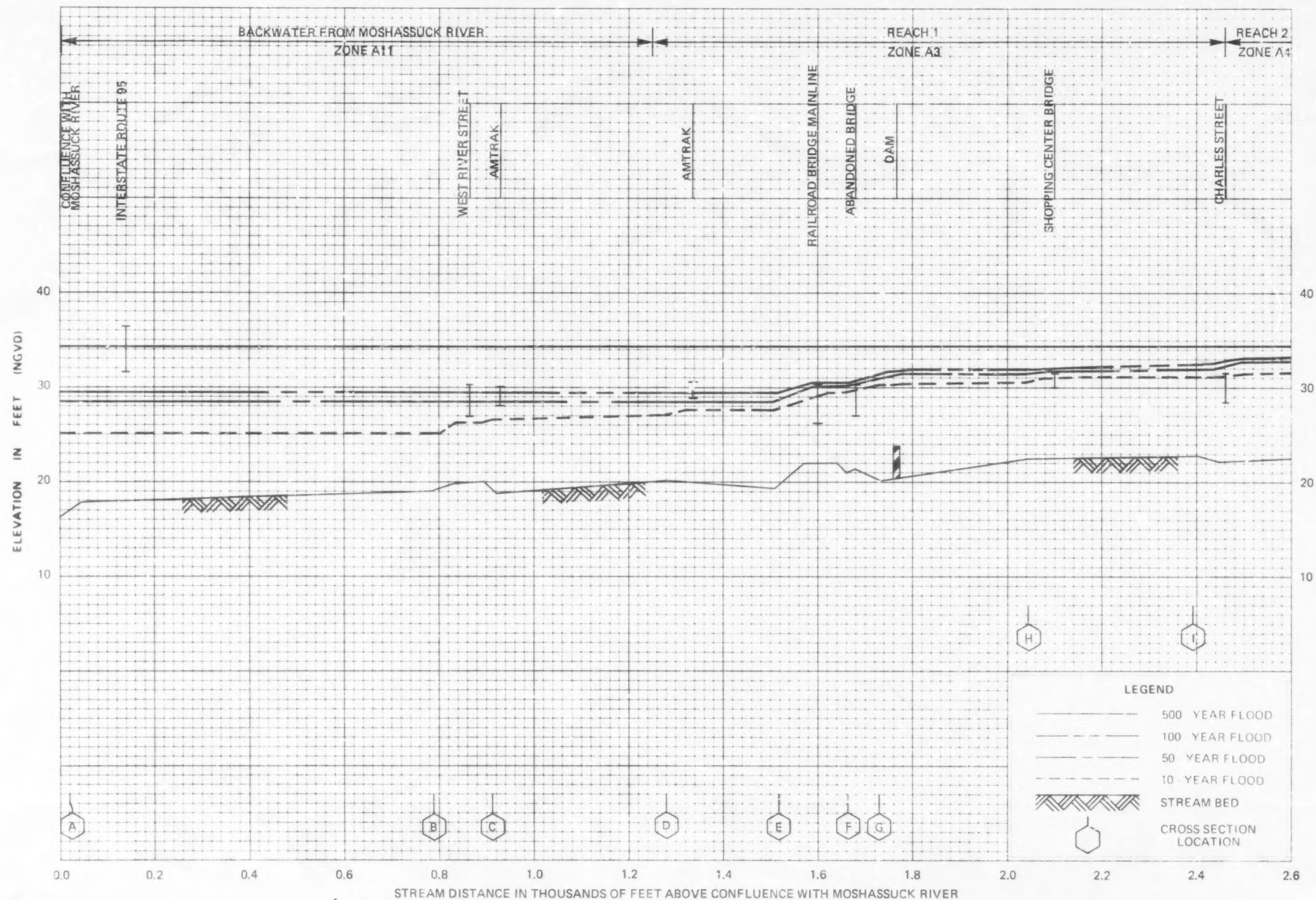
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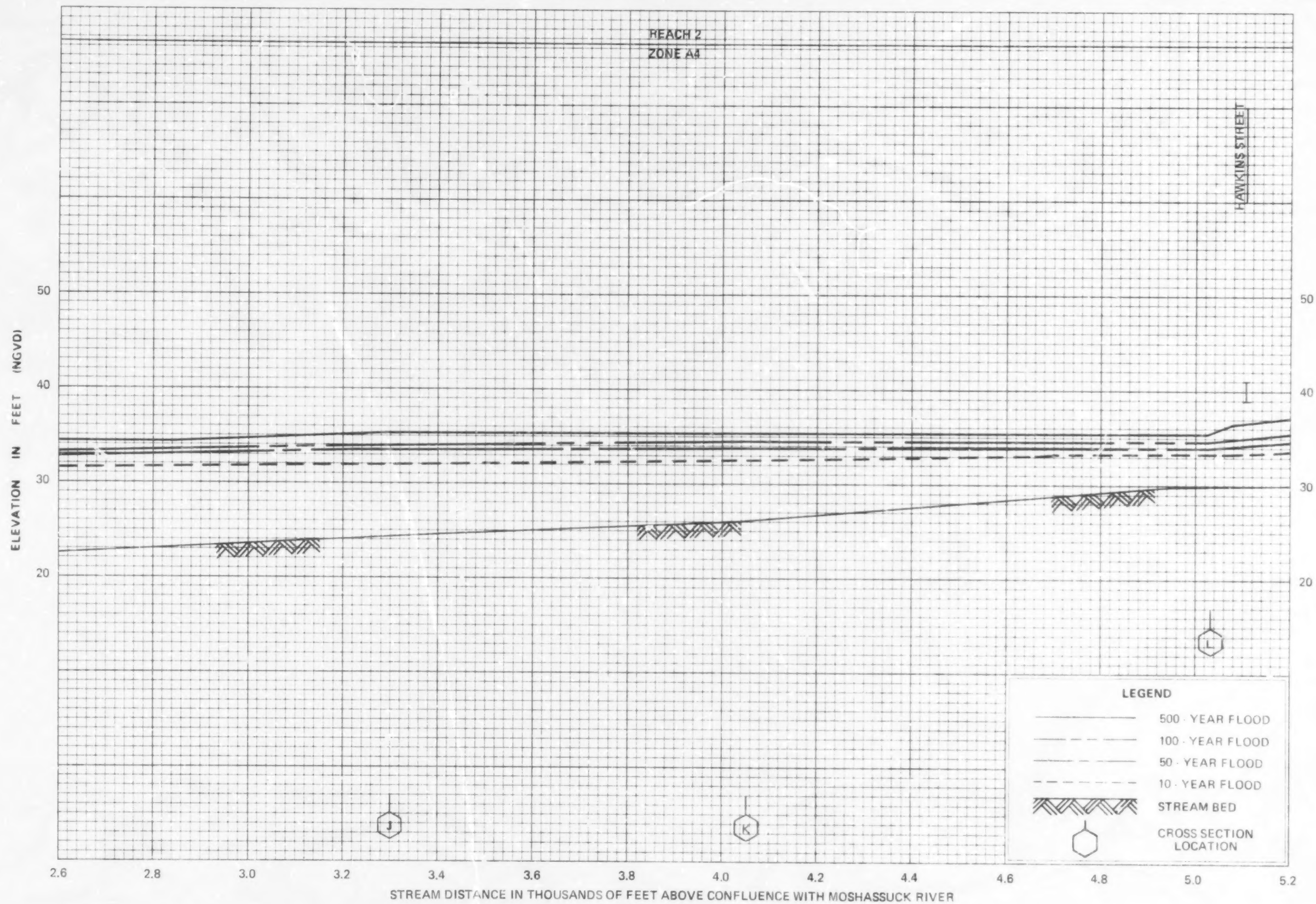
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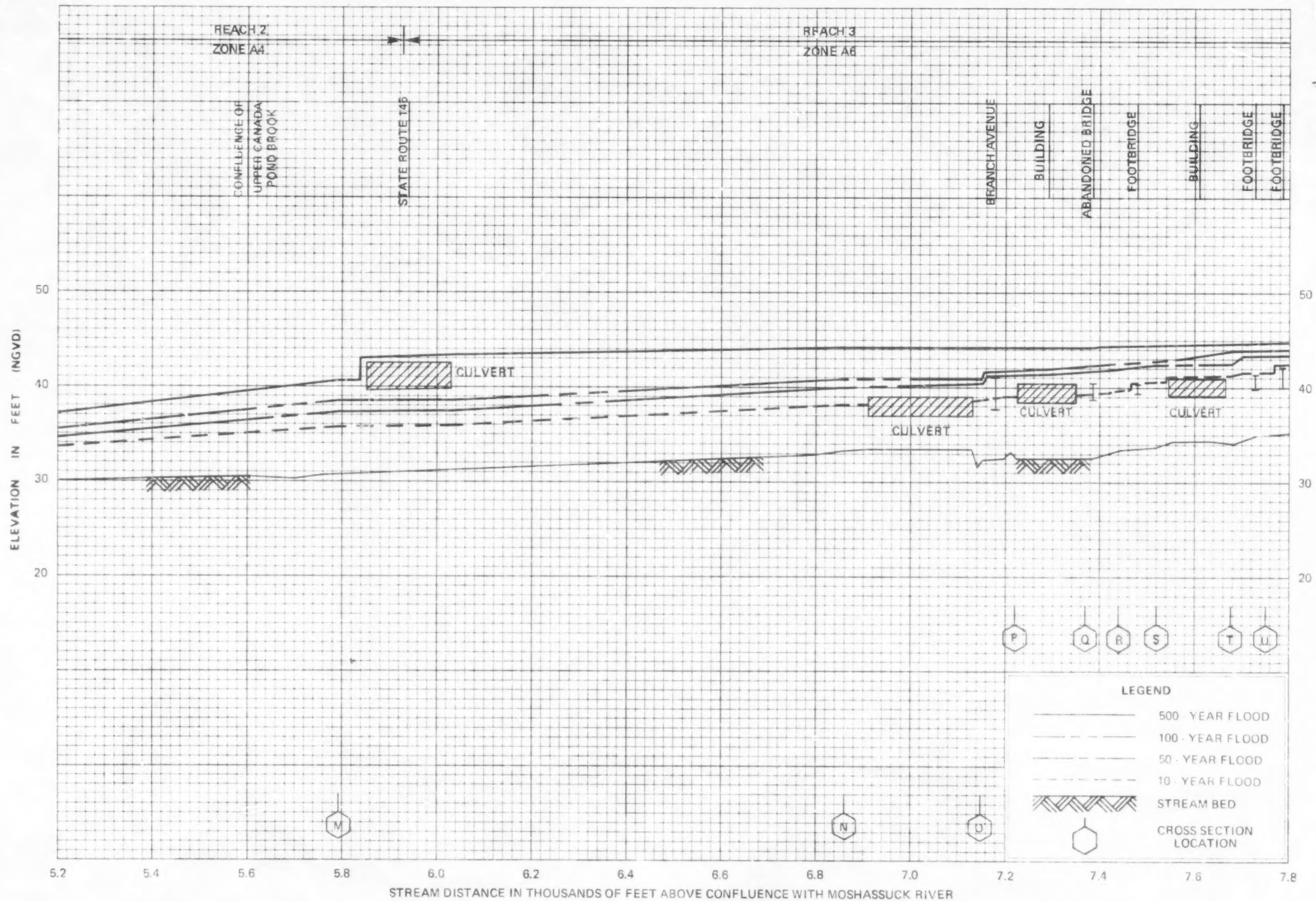
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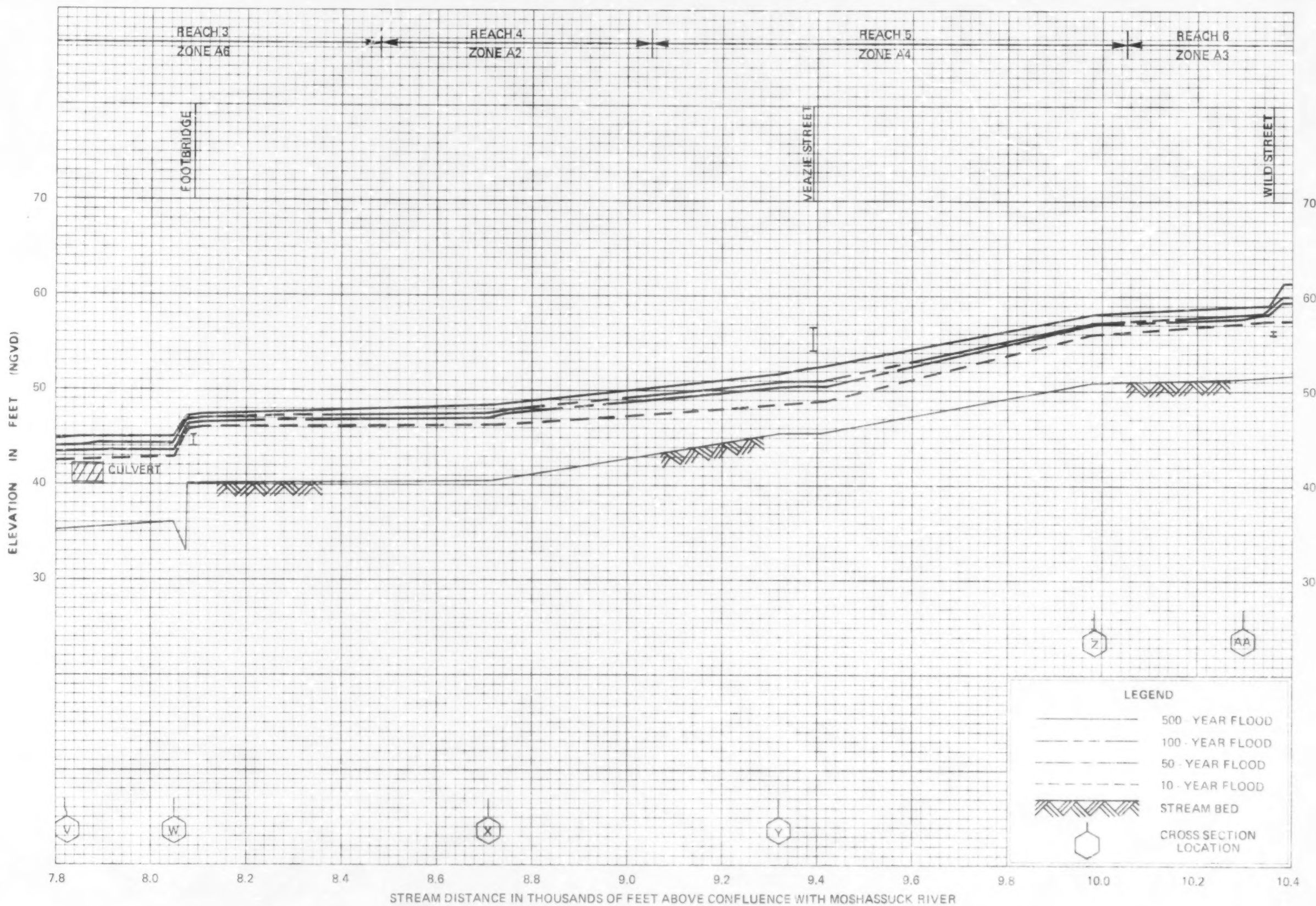
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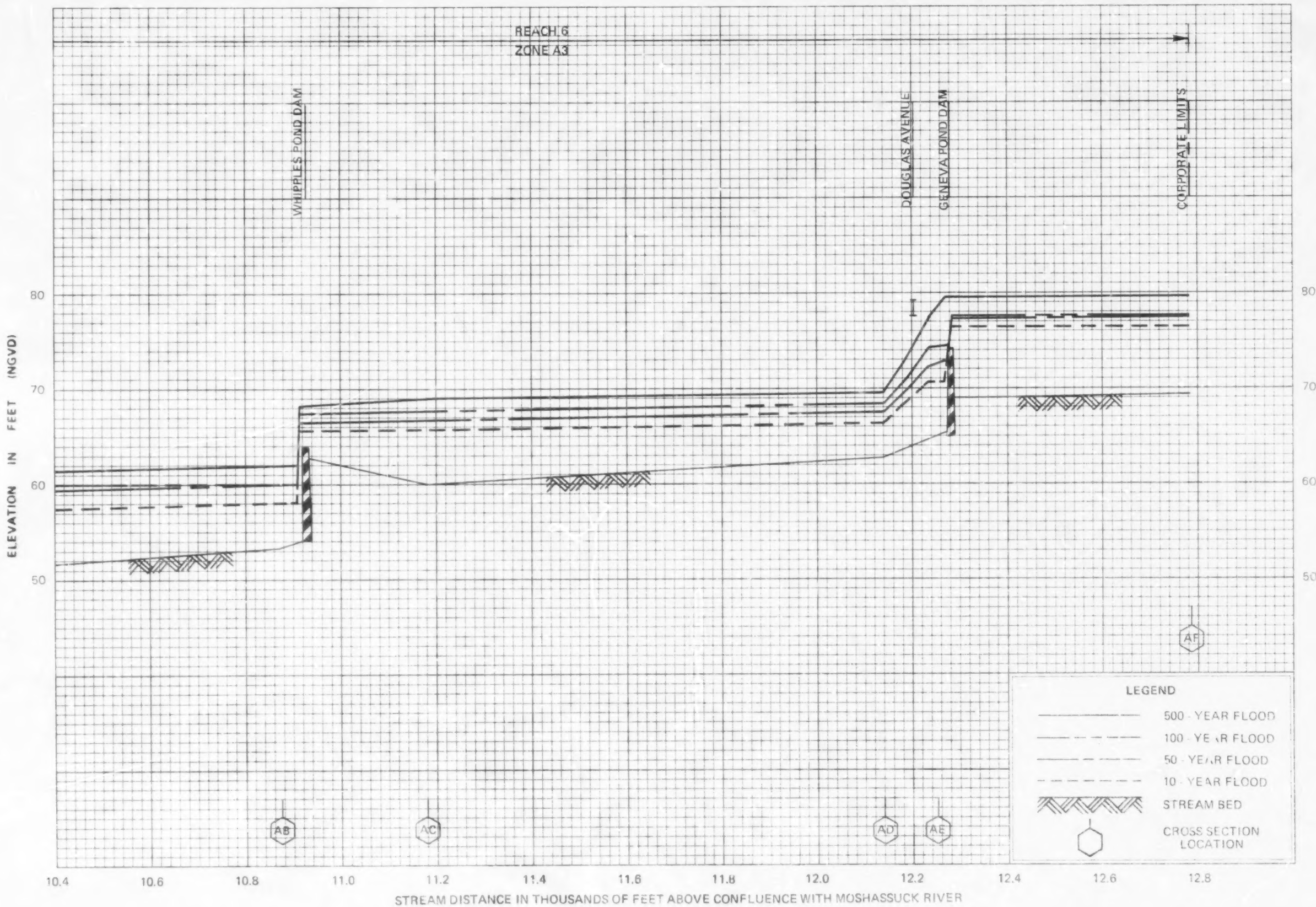
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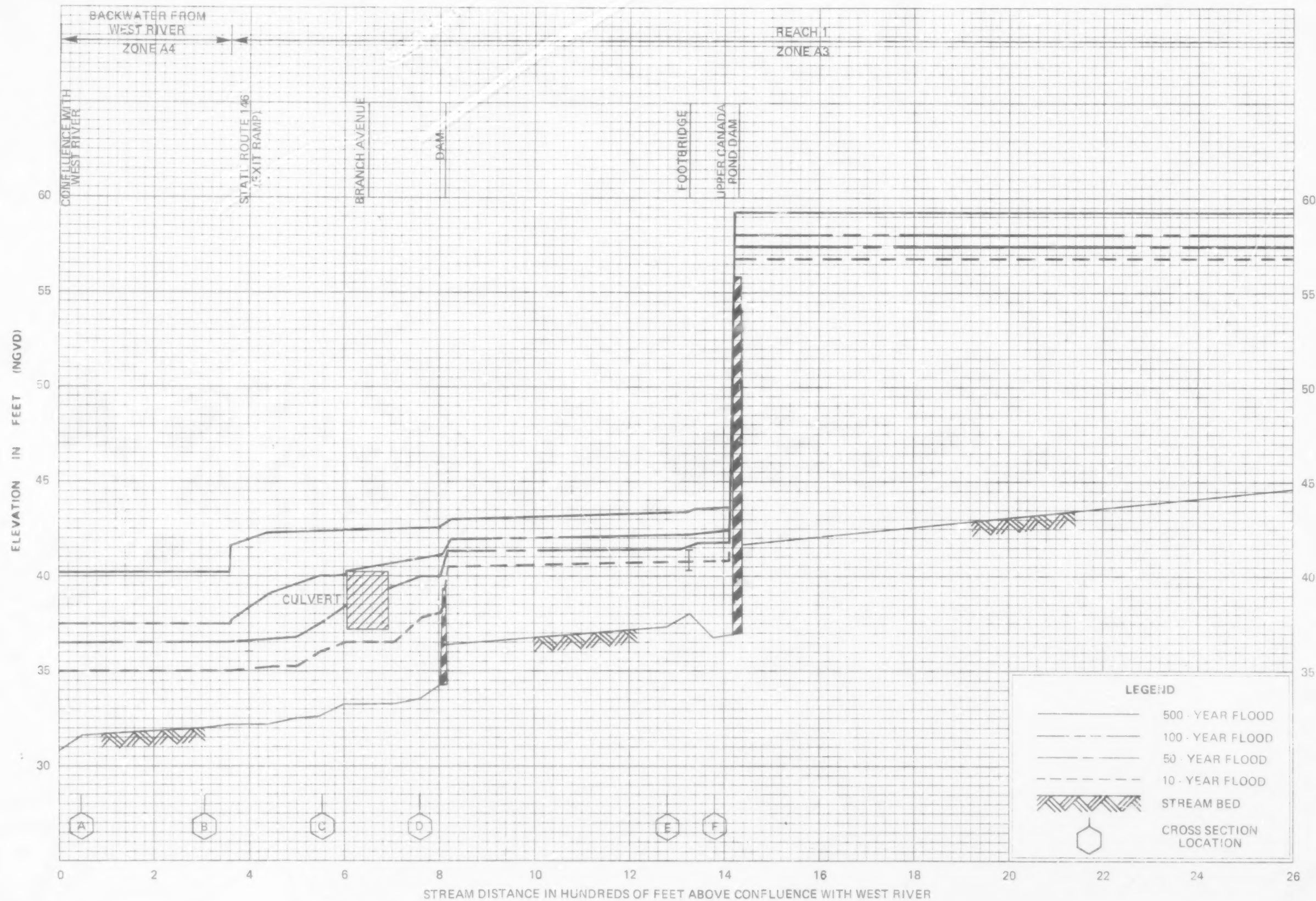
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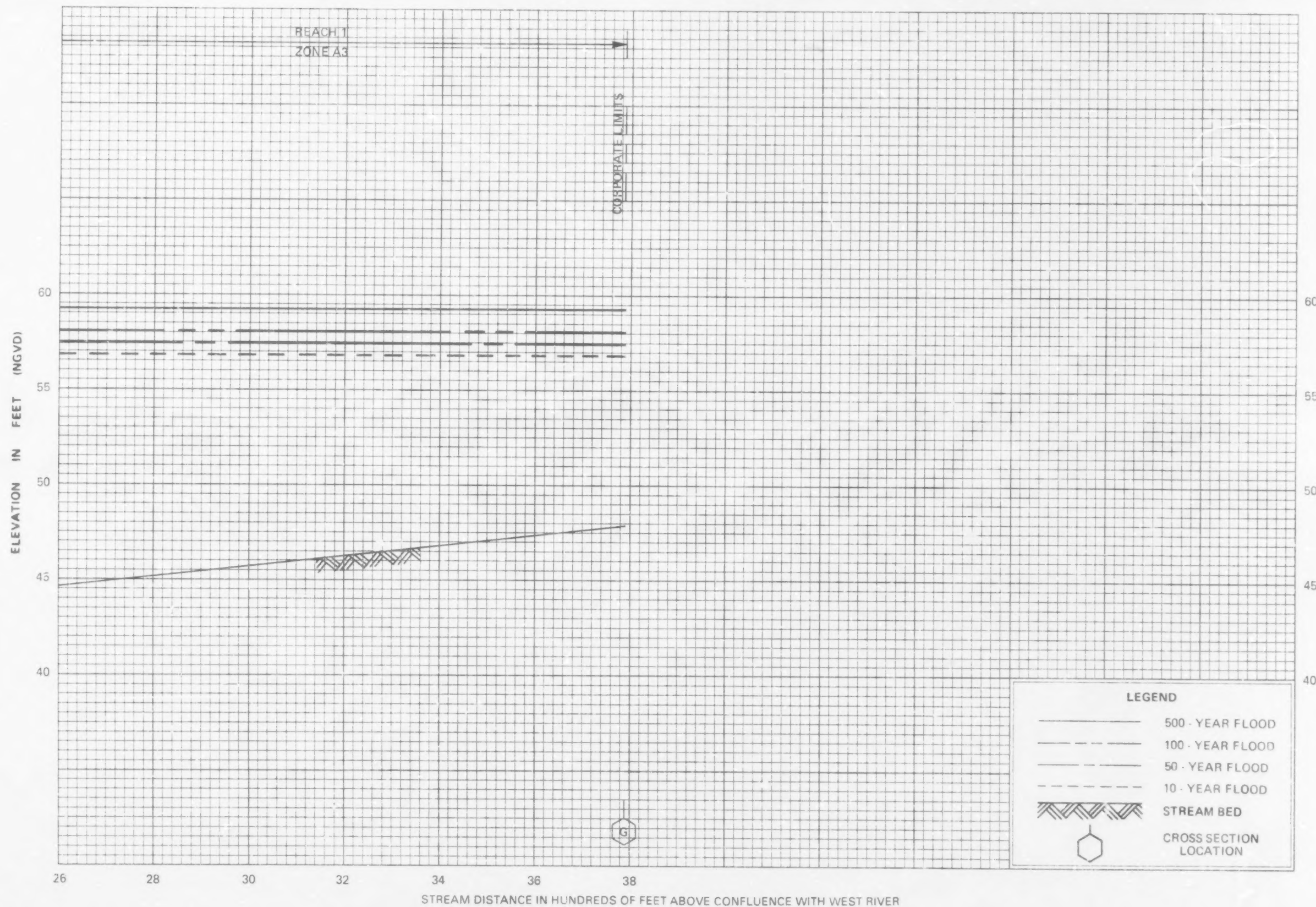
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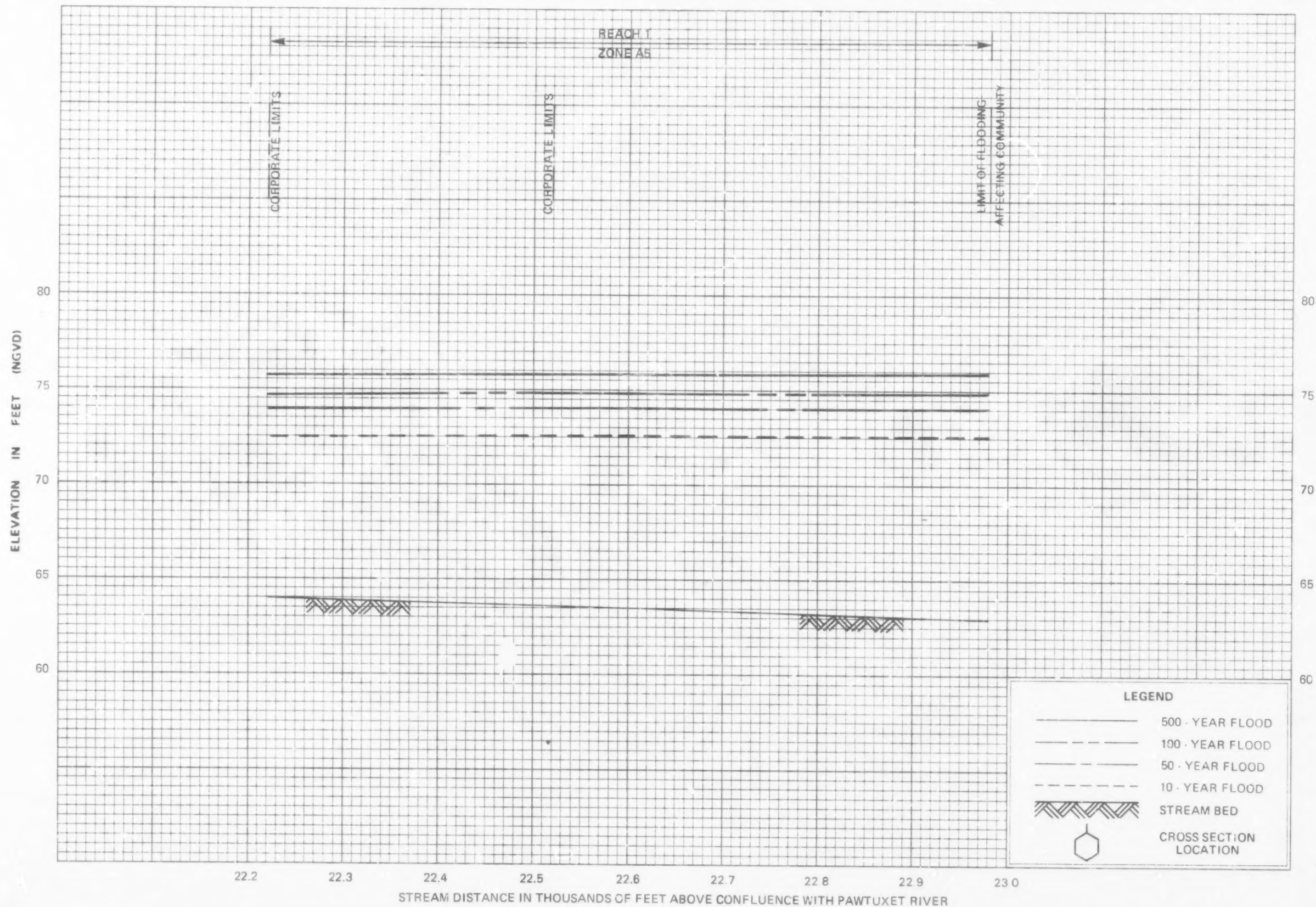
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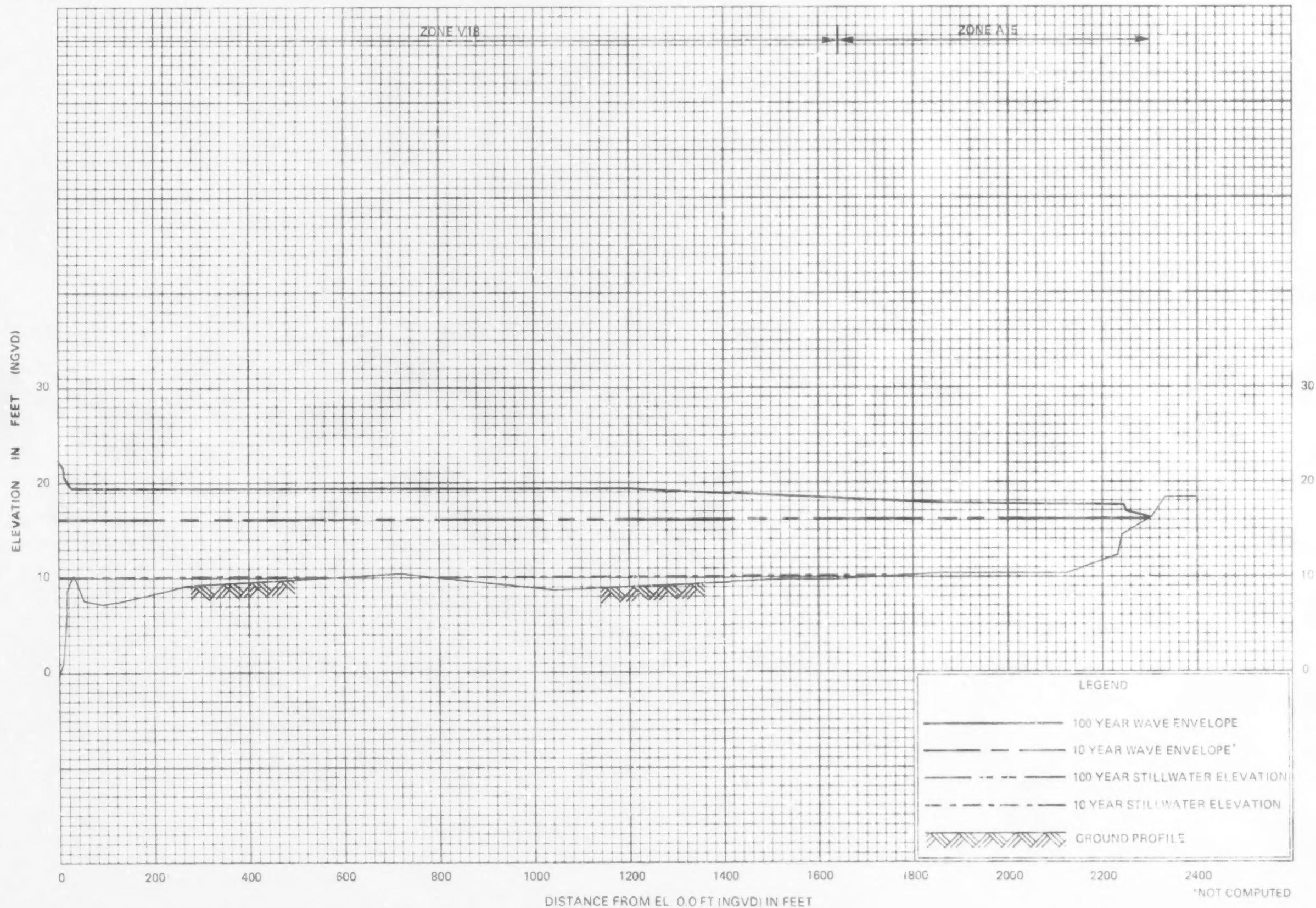
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FLOOD PROFILES
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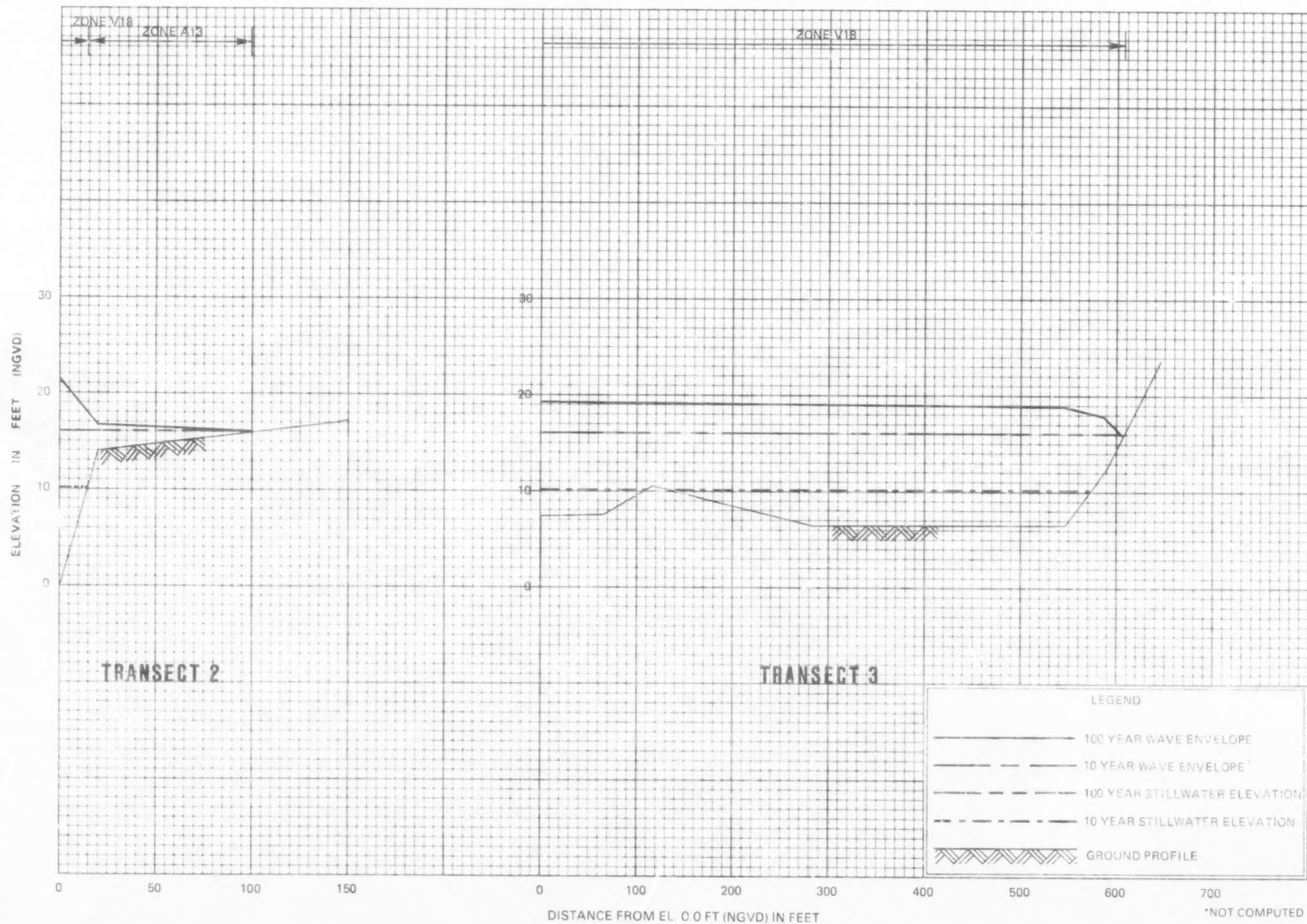


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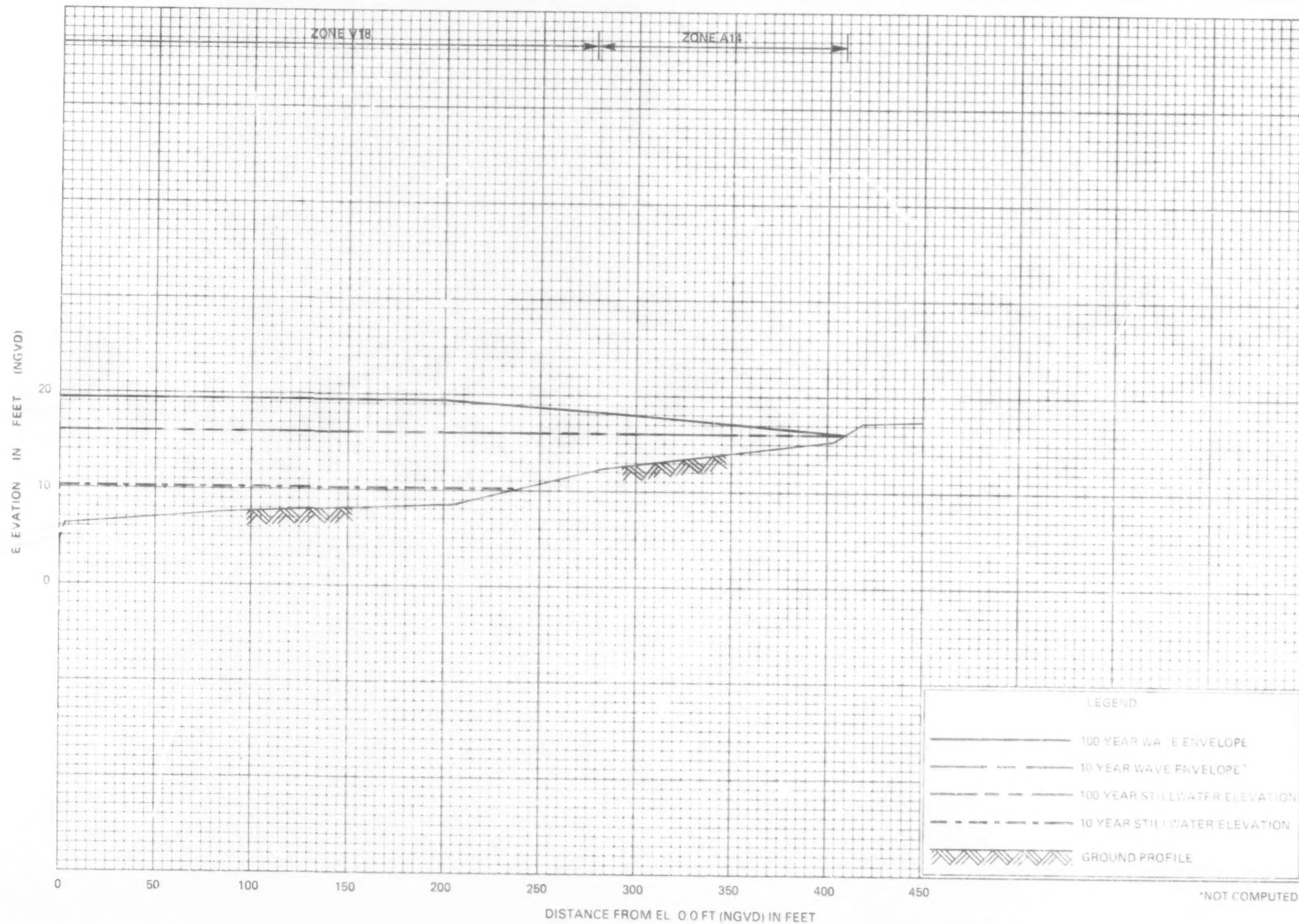
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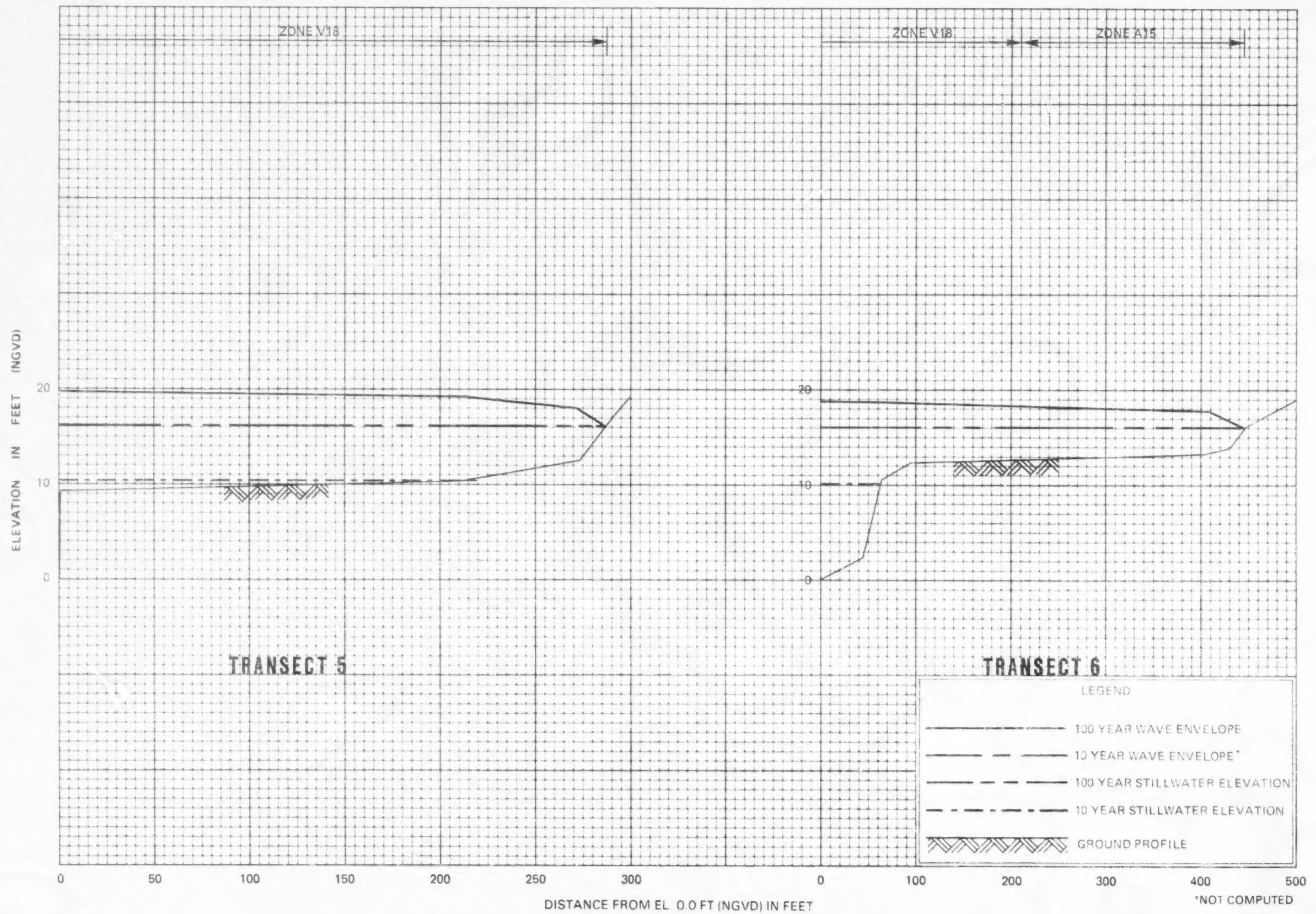
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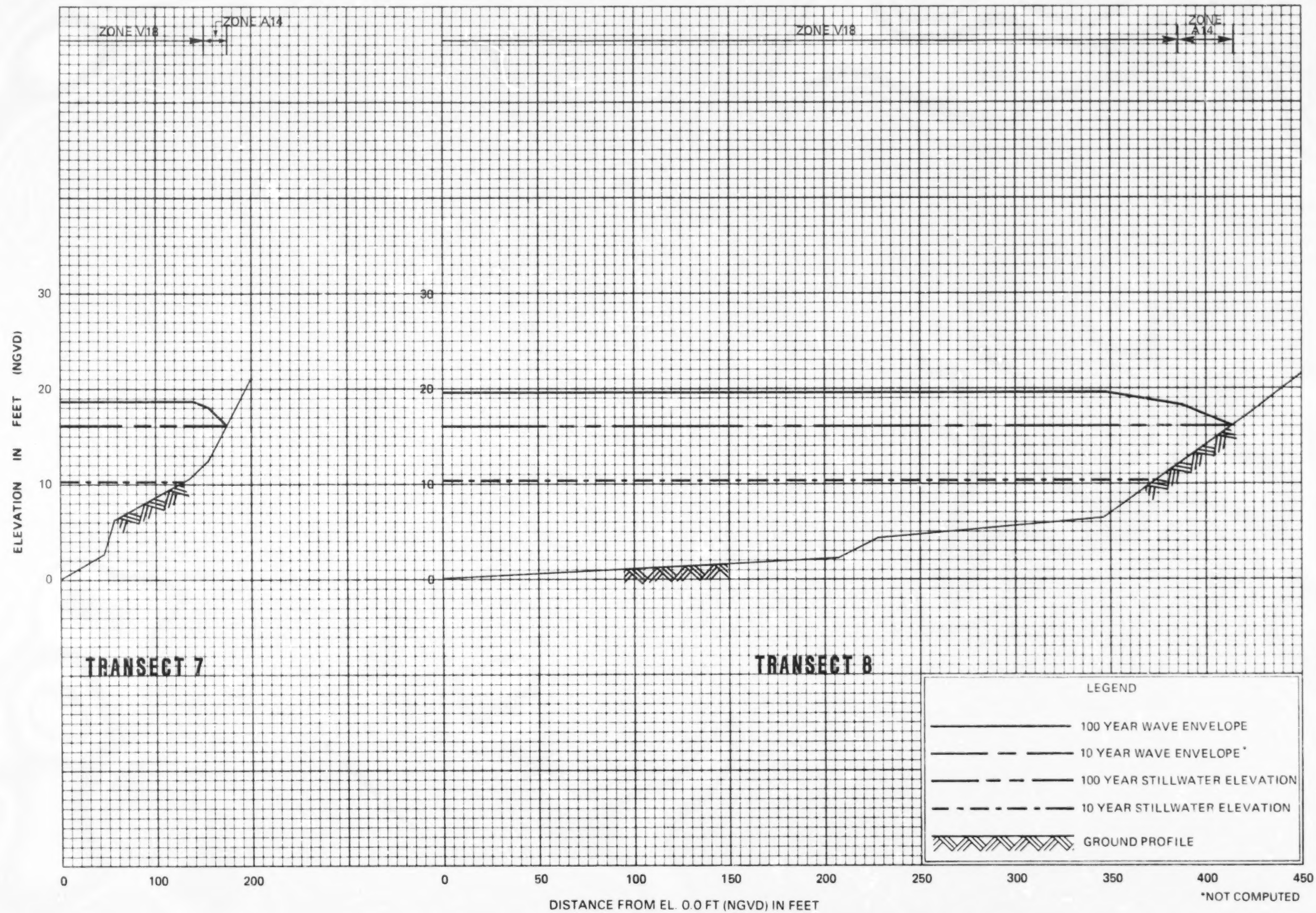
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